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ORGANIC POLARITY
SOME ECOLOGICAL AND PHYSIOLOGICAL ASPECTS

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INTRODUCTION

THE polarity with which I propose chiefly to deal, is that interesting and quite well-known sequence of communities, species, forms, and physiological groups that are found in a uniform medium as it stretches from the equator towards either pole.

Johnstone (57) among others, has already stated the matter in part. Considering the work of the German planktologists, Hensen and his collaborators, and the observations of other naturalists, he concludes that the warmer waters of the world produce less abundant but perhaps more varied plankton and that the algal flora and benthic and nektic life is poorer in warmer than in colder seas. This difference is in the opposite sense to the distribution of terrestrial life, which is densest in the tropics and diminishes towards either pole, apparently in direct relation to the intensity of sunshine and temperature. The chemical and physical aspects of this question have been raised by Sir John Murray (78) who points out that there are in the sea three surface zones of different character. The first is the circumtropical zone, where there is a high temperature throughout the year and an annual range not exceeding 10°F. Here is the area in which live all those organisms which form massive skeletons of calcium carbonate laid down chiefly as aragonite; here also metabolic changes take place very rapidly and pelagic larvae area bundant. Between the circumtropical and circumpolar zones are two zones in which the temperature range may be as high as 45°F. causing a great destruction of animal life with a consequent deposition at the bottom of the ocean of phosphatic and glauconitic nodules. In the circumpolar zones there is a low temperature with an annual range not exceeding 10°F. and in which such little calcium carbonate as is found in living organisms occurs in the form of calcite. The metabolic changes take place slowly and pelagic larvae are almost absent. Murray goes on to suggest that in a warm zone an organism may pass through its whole life-cycle in a few hours, days or weeks, whereas a similar organism in polar waters may take years to pass through a similar life-cycle. Further-

more, he points out that the optimum temperature for most vital enzymes is blood heat and that none is known to have an optimum temperature as low as that in which polar invertebrates must live.

In his recently published work *Tiergeographie des Meeres*, Ekman, (29) who is more particularly concerned with the systematic aspect of animal distribution, recognizes in his consideration of "bipolarity", a bipolarity of parallel phenomena. The bipolarity considered by Ekman is chiefly one of related forms that have become discontinuously distributed, but the bipolarity of parallel phenomena is characterized by ecological differences such as greater numbers of individuals, the greater size of these individuals, thinner shells and greater brood-care towards the poles. It is also shown by the circumstances that a family or genus inhabiting cold or temperate areas has a greater number of species than is the case in tropical seas, and finally by the occurrence of species living in the seas of lower latitudes and from each of which may be derived a different species or variety which is found towards either pole. This latter sort of bipolarity is called the bipolarity of taxonomic parallel development (*Bipolare taxonomische Parallelentwicklung*).

Discussing the ecological differences in another part of the book, Ekman accepts as a fundamental principle Thienemann's generalization that the more an environment departs from the normal and the more specialized and extreme it becomes, the poorer it becomes in species and the richer in numbers. The implication of this statement is that the colder seas present an extreme and specialized environment compared with a normal and optimum area in the tropics. This definition of the two areas is the one which I am not disposed to accept for reasons which will appear later.

My purpose in the argument that follows is to develop some of the conclusions and speculations just mentioned. Briefly I conclude that the gradient of radiant energy in an otherwise nearly uniform medium like the sea, sets up a gradient of assimilation in living things. This results in organisms living more quickly, showing a greater variety of form, often accumulating different end-products, occurring in more complex communities and being present in less total mass, area for area, in the tropics. At any place on this gradient, differences of season, passive convection and vertical distribution may produce conditions similar to another part of the gradient.

I have also attempted to relate the ratio of the sexes in particular species of organisms to the polarity that has just been defined. Assuming the metabolic theory of Geddes and Thomson (35) we should expect to find the females of any species more successful where the food conditions are best, and the males where food conditions are unfavorable. Also, other things being equal, we should expect to find the quicker metabolism of the males favoring their relative increase at the hotter end of the range of any one species. That these relations do actually occur is, I think, shown by my evidence. The amount of observation available concerning the size, number, physiology, and distribution of living things that might serve my purpose is necessarily enormous.

The generalizations I am about to make are therefore drawn from instances I have come across in the course of other work, general reading, and also occasionally from my own investigations. Many of these instances are quite well known, but I do not think they have been presented in such a way before. As the land areas present an environment of extreme complexity, most of my examples are taken

from the sea, where conditions are more uniform and effects are likely to be more simple. Nevertheless, I have not hesitated to deal with terrestrial organisms in certain parts of my argument, particularly in the section on sex-ratios.

Finally, I cannot pass from this introduction of the factors I am about to deal with in respect of the distribution of organisms on the earth's surface without mentioning the qualitative parallelism they exhibit to the physiological gradients already established in individual organisms. Metabolic gradients are well known as the result of the work of the embryologists who have shown that there is a gradient both in activity and in chemical composition between the animal and vegetable pole in the eggs of certain vertebrates. Similar gradients in adult organisms have also been shown. The considerable data available in this field has been well marshalled by Child (19) who has been responsible for many of the important experiments demonstrating axial gradients. When discussing metabolic gradients in eggs, the term "polarity" is often used and though the term "bipolarity" denotes the faunistic resemblances of the seas at two poles in contrast to the conditions of things at the tropics, I have retained the more simple word "polarity" as the title of this paper, thinking it better to stress the essential unity of the phenomena discussed here with those of a wider field.

AN ASSIMILATION GRADIENT

The work of Hensen (46), Lohmann (68), Hentschel (47), and others has shown that there is a general increase of plankton organisms as one moves from low to high latitudes in the ocean. This increase applies to both plant and animal elements. For the North Atlantic it has been usefully expressed by Harvy (45) in the table adopted from Lohmann's work (Table 1), showing the phytoplankton organisms per litre between the surface and 400 metres.

The diagrams reproduced in Fig. 1 are from Hentschel's work and show the same conditions rather more fully for the microplankton and Metazoa of the South Atlantic. The conditions necessary for the growth and reproduction of plankton algae upon which the rest of the plankton depends, are a nutrient medium containing a sufficient inorganic food supply and the radiant energy of the sun. The sea forms such a medium, but Atkins (6) and Harvy (43) have shown that the growth of algae

TABLE 1

Frequency of phytoplankton organisms in different latitudes

Latitude.....	40°–50°N.	30°–40°N.	20°–30°N.	10°–20°N.	10° N.
As found in....	May	June	June		
	6,000	2,000	600	500	600
Surmized mean for whole year	3,000	1,000	600	500	600

may utilize completely now the available supply of phosphates and now that of nitrates. Both these salts are necessary for the elaboration of living protoplasm and their absence sets a limit to further growth. Other salts or elements occurring in sea water in minute concentrations may also be necessary for the growth of algae. For instance, recent investigations made by Gran (39) have stressed the importance of iron compounds. Nevertheless, the availability of phosphates and nitrates broadly fits the observed facts of algal distribution.

Now the distribution of these two important ultimate foodstuffs, phosphate and nitrate, shows that they occur in relatively large quantities in the deeper water of the

great oceans, both in the tropics and the polar regions. But at the surface of the oceans, and in the shallower water near the coast, or submarine banks, there is no such uniform abundance. In high latitudes in the winter and spring, the amounts of phosphate and nitrate in the surface water of the oceans may be far greater than those found in the warmer parts. This phosphate and nitrate is subsequently almost entirely used up by enormous outbursts of algal growth. In South Polar seas, however, Deacon (25) has recently shown that the very great amounts of these nutrient salts present at the surface are not exhausted in this way even at the times of vigorous algal growth.

In Fig. 2, I have constructed a composite chart showing the milligrammes of phosphate at different depths in the Atlantic between the North and South Poles and based upon the results of Krebs and Verjbinskaya (61), Atkins (7), Thomsen (116), and Deacon (25).

An attempt to explain the distribution of ultimate foodstuffs in the surface waters of the great oceans may be helped by a consideration of this figure, for though the nitrate values have not been plotted their behavior is similar. In warmer seas the nutrient salts mentioned are used up as soon as they become available in the upper water layers. This is on account of the powerful and abundant solar radiation available for photometabolism throughout the year. But in boreal seas, solar radiation is less intense and insufficient for any considerable photometabolism in the winter. During this period the surface water, which has become sharply separated from the deep layers by its higher temperature, cools, and becomes heavier and therefore sinks. This causes vertical mixing and results in the bringing of phosphate- and nitrate-rich water to the surface. On the arrival of the long light days the conditions are fulfilled for the enormous abundance of algal growth mentioned above. The

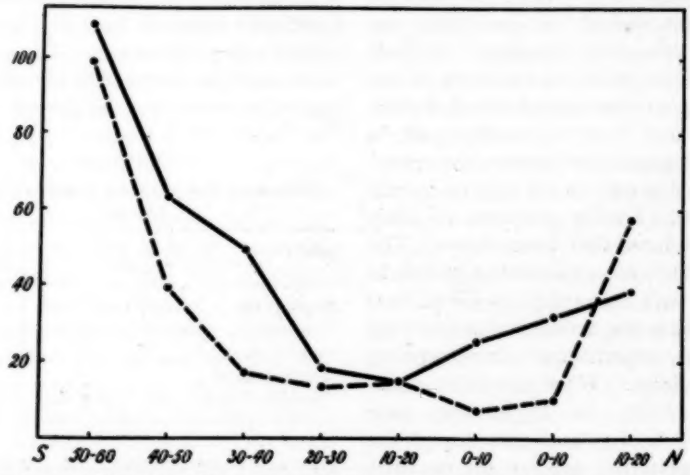

FIG. 1. THE AVERAGE CONTENT PER LITRE AT 0 AND 50 M. FOR NANNOPLANKTON (BROKEN LINE) AND PER FOUR LITRES FOR METAZOA (CONTINUOUS LINE) GROUPED ON THE ABSCISSA AT 10° LATITUDE INTERVALS FOR THE ATLANTIC

The figures on the ordinate represent 1000s for the nannoplankton and units for the metazoa (After Hentschel)

shortening summers and more rigorous winters of increasing latitudes give not only a much deeper exchange between the surface and the deeper waters, but this exchange continues longer and longer into the time of algal reproduction. This difference in vertical mixing, fundamentally a temperature effect, is no doubt the principal cause of the observed increasing abundance of oceanic microplankton with latitude.

There is, however, another factor which would produce a greater mass of microplankton plants and animals in higher latitudes. This is the direct effect of temperature. According to the Van't Hoff generalization, a rise of 10 degrees centigrade brings about an increase of approximately double the rate of vital metabolism, when this change is applied within the range the species is capable of tolerating. This would mean that organisms in higher latitudes would be able to conserve their same mass with less energy. In the case of the algal producers, this might be offset by a correspondingly lower rate of production of the food from which the energy would be obtained. According to the work of Kniep (59) this is not the case in the brown alga, *Fucus serratus*, where a decrease in temperature was found to lower the rate of respiration to a greater extent than the rate of photosynthesis. Whether this is generally the case or not, it seems clear that the animal plankton would be able to live more economically on the same amount of algae.

There are two other factors that may have favorable effects on the production of algae in higher latitudes; one is the effect of polymerized water due to the melting of ice, and the other is the greater solubility of CO_2 in the colder water. There is not yet, however, sufficient data bearing on these two effects to permit a fruitful discussion.

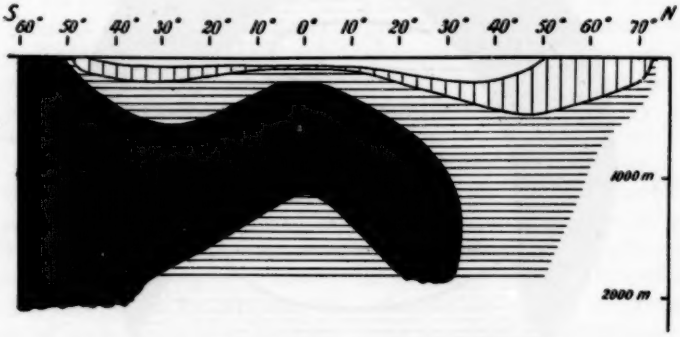

FIG. 2. SCHEMATIC SECTION OF THE ATLANTIC SHOWING THE DISTRIBUTION OF P_2O_5 AT DIFFERENT LATITUDES AND DEPTHS
The contours are at 30, 50, and 100 mgms. per cubic metre

In addition to the conditions just mentioned, there are two ways in which solar radiation might be expected to operate more favorably for plant reproduction in the tropics. Firstly, the annual solar radiation is greater in the tropics (though that of a long polar summer's day is greater than that of a tropical 12-hour day) and light penetrates further into the sea, shortening the distance that regenerated phosphates and nitrates would have to move upward. Secondly, the high surface temperatures of tropical seas, will

give rise to much evaporation, causing a cooling and a mixing of the superficial layers throughout the year. Nevertheless, the factors working in the opposite direction discussed at the beginning of this section obviously outweigh these two particular effects of solar radiation.

There must be mentioned here also the fact that the regularity of this production gradient is often upset by upwellings of

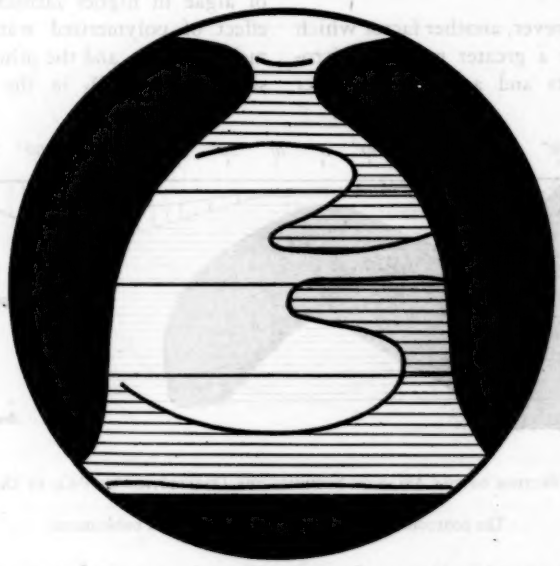

FIG. 3. GENERALIZED PICTURE OF THE DISTRIBUTION OF PLANKTON IN ANY OCEAN
The plankton-rich parts are indicated by parallel lines (After Hentschel)

salts due to currents, tides and turbulence in the neighborhood of submarine slopes and the incursion of river water near the coast. This results in favorable conditions for plant growth and a profuse flowering.

An instance of upwelling occurs near the equator, and the effect on phytoplankton abundance is shown in Table 1, where it will be noticed that the number of organisms between 0–10 degrees N. is greater than that between 10–20 degrees N. (Fig. 3). Another case of upwelling having similar effects takes place off the coast of California.

This section may be concluded by saying that there is a general increase in microplankton abundance with increasing latitude in the great oceans, and that this is fundamentally an increase of the photosynthetic plants and their more successful assimilation. The cause of this gradient of assimilation is a gradient of solar radiation. This acts indirectly by establishing a gradient of thoroughness in the mixing of food—rich deep water with the exhausted upper layer—and directly but perhaps not so importantly by increasing the rate of living in the warmer waters, without the presence of the means for a corresponding assimilation.

VITAL VELOCITIES

The building up of living matter takes place in two ways. In one, the substances produced by living things or the living

things themselves are utilized. In the other, inorganic substances are absorbed and united within the body of the organism to make organic matter with which to build up the living protoplasm. Plants utilize this method and animals the former. In the marine plankton the plant type of life is sometimes called "producer" and the animal type "consumer" plankton.

It is clear that the relation of all living things to that part of the inorganic environment which is essential to assimilation will be governed by the plants. Another way of presenting the matter is to consider the position of plants among all living things as a group that stands nearer the building up or anabolic side of the great vital process which is constantly building itself up and breaking itself down. On the other hand, animals, starting with the assimilation of substances that are the end results of the plants' activities, must be considered as relatively nearer the break-down or catabolic side of the life process as a whole.

While the energy used by the plant in the course of assimilation is very great, the result is an organism that achieves growth in bulk, but is usually devoid of kinetic activity. The animal, however, not only grows, but frequently utilizes the energy obtained from its organic food in movement. The rate of living is relatively increased, and the break-down processes take place at a greater rate than in plants. In most animals indeed, there are special organs of excretion to deal with the rapidly formed and copious end-products. Notwithstanding this general division of animal and plant, or "producer" and "consumer", types of life there are certain organisms shortly to be mentioned that behave on the whole as producers, but exhibit certain features of the consumer class.

In the light of what has just been said let us consider the distribution of some of the largest and most important groups of organisms in the great oceans. To the plants belong a great community, the algae, on whose photosynthesis of inorganic matter into organic, the greater part of the rest of the life in the sea depends. Of the algae the most important and widespread group is that of the diatoms, but it is towards the poles that this group has its greatest absolute and relative abundance. In lower latitudes diatoms are replaced in importance by the calcareous and flagellated Coccolithophoridae and the blue-green genus *Trichodesmium* as the dominant algae. In the hottest waters the dominant producer community is that of the peridinians. The peridinians are unicellular organisms capable of photosynthesis but protected by a wall of cellulose plates and not by a siliceous one as is the case in diatoms. They are also provided with powerful flagellae seated in special grooves on the surface of the body. These flagellae are organs of movement and like those of the Coccolithophorides already mentioned endow their possessors with the power of movement. As groups, therefore, the peridinians and Coccolithophoridae resemble the animals in that they are kinetic, and so must be regarded as living more quickly than the diatoms of the plankton. The sequence of communities just discussed is shown in Fig. 4 which is taken from Hentschel's (47) plankton survey on the "Meteor's" expedition to the South Atlantic and which together with Figs. 1 and 3 he has kindly allowed me to reproduce. In parts of the world where there are marked seasonal changes the spatial sequence of communities that have already been mentioned is essentially repeated in time. Discussing the results of the periodic plankton cruises of the International Investigations in Northwest Europe, Gran (38) says

It is characteristic for the yearly period of the plankton for the whole of our area, that the development after the winter rest commences everywhere with a strong flowering of diatoms—succeeded by the next stage in the development, the *Ceratium* (peridinium) plankton which with comparatively unimportant modifications is usually prevalent throughout the summer.

experience of all planktologists working in temperate latitudes.

Turning to fresh water it is significant for the present argument to note that West (124) says of the peridinians that they occur in Britain only in the summer, but are found perennially further south. In

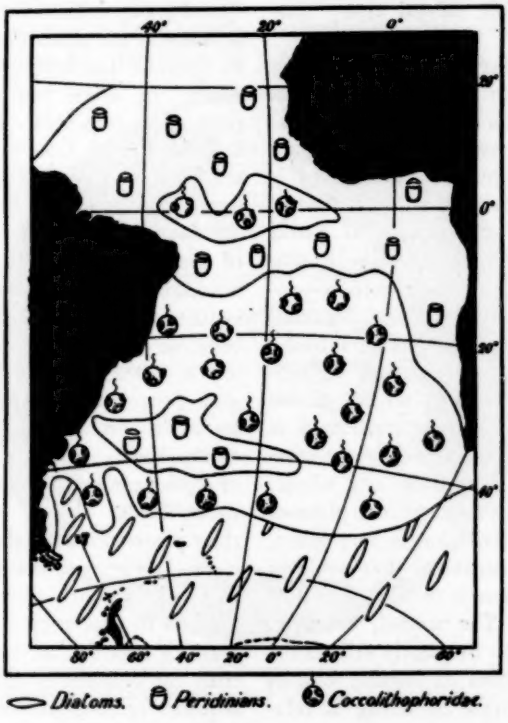

FIG. 4. CHARACTERISTIC NANNOPLANKTON ORGANISMS IN DIFFERENT ZONES OF THE ATLANTIC (After Hentschel)

In addition it may be said that the larger zooplankton organisms behave like the peridinians in that they follow the diatoms. There is usually a secondary outburst of diatoms in the autumn, but they are often of different species, and later I shall suggest that there are physiological differences. The annual sequence described here has been the general

fresh-water lakes vast masses of blue-green algae may occur in the still hot water of high summer long after the spring diatom outburst. Some of these species possess a peculiar power of movement, the nature of which is not yet properly understood. Blue-green algae are further notable in that some of their species are found found at the highest temperature known

to be tolerated by living organisms, when they occur in hot springs at as much as 78°C.! The seasonal occurrence of blue-green algae in fresh water recalls the masses of *Trichodesmium* found in the warmer parts of the ocean.

I began this section by defining animals and plants as organisms of different types of assimilation, the animal type consuming the results of the plant type's production and living at a greater rate. I also show that certain important groups of producer plankton of tropical and temperate seas were absent from the neighborhood of the poles and that these groups bore indications of a quicker and more animal type of metabolism. Thus the hotter regions, as we might expect, favor the more catabolic types of metabolism among the producers by a general increase of vital velocities. At first sight this acceleration of vital velocities also might be thought to favor the animal and consumer plankton in contrast to the producers. It must be remembered, however, that if, as is very broadly true, the vital rate of wastage is doubled for 10°C. rise in temperature, the consumer plankton would need twice the amount of producer food in order to maintain its original bulk. This means that, with the same amount of producer food at the two temperatures, the proportion of consumers supported by producers at the higher temperature would be halved. The proportion of consumers to producers should, therefore, fall as the temperature increases. A further inference from this thesis is that if the amount of producer plankton were the same at the poles and the equator, the total plankton at the equator would be less as a direct result of the gradient of solar radiation causing a less proportion of consumer plankton at its higher end. Actually as we saw in the preceding section the producer plankton is itself less at the equator than at higher latitudes.

The general relations between producer and consumer plankton expected on theoretical grounds appears to occur in nature, for according to Lohmann (68) the mean ratio of Protophyta, Protozoa and Metazoa in the centrifuge plankton of his "cool areas" was 741;73;1, and for tropical areas 458;24;1.

The matter can be summarized by saying that in the microplankton there is an absolute and a relative preponderance of kinetic compared with static organisms as we approach the equator, though Lohmann's careful work shows that the photosynthetic species are supporting relatively less consumers.

FAT AND CALCIUM CARBONATE

Fat

Brandt (16) and Delff (27) for marine plankton, and Birge and Juday (14) for that of fresh-water lakes, have shown that relatively more fat than carbohydrate was laid up by diatoms as compared with peridinians. For other motile microplankton organisms, Delff (27) gives less than 2 per cent of fat and over 60 per cent of carbohydrates for a sample of the radiolarian *Collozoum inerme* from the Mediterranean and I have found ether-soluble matter values of 2.7 per cent and 3.3 per cent of the dry weight for the flagellates *Phaeocystis* sp. and *Noctiluca miliaris*—lower values than those shortly to be given for diatoms from the same area.

The low fat and higher carbohydrate values indicated by these results for motile organisms are significant, when we remember that physiologists have shown that only a carbohydrate can be readily utilized for muscular movement. The relatively greater amount of this easily mobilized food reserve in the more kinetic

organisms seems, therefore, an inevitable physiological side of their motility and their generally higher position on the temperature gradient.

As showing an increased percentage of fat at a lower temperature, it is interesting to compare the 2.07 per cent of dry weight for the diatom *Aulodiscus kittoni* at the time of its maximum in May on Copalis Beach, Washington, and at a temperature of 13°–16°C. (11) with my comparable and hitherto unpublished estimates of 28 per cent–48 per cent for *Coscinodiscus concinnus* during its maximum in May, 1933, when it was found on the Dogger Bank at a temperature of 6.5°C.–10°C. For a wider latitude range, I have determined a series of 17 fat percentages for coarse net plankton samples which have been averaged in 20° groups in Fig. 5 against latitude, with which the fat values show a tendency to correspond. The material was almost entirely zooplankton collected in the upper water layers of the North and South Atlantic and the Indian Ocean. I am indebted to the late Mr. J. O. Borley and Dr. Stanley Kemp for the "Discovery" collections and to Mr. M. Graham for those made by the Ministry of Agriculture and Fisheries research ship "George Bligh."

A number of similar estimates for Hensen net hauls made in June and October, 1932–1934, in the western North Sea, and consisting mainly of zooplankton have been correlated with the corresponding bottom temperatures in the list below:

Year	Month	Number of Stations	r
1932	June	30	−0.76
	October	27	−0.42
1933	June	35	−0.67
	October	27	−0.45
1934	June	32	−0.63
	October	26	−0.435

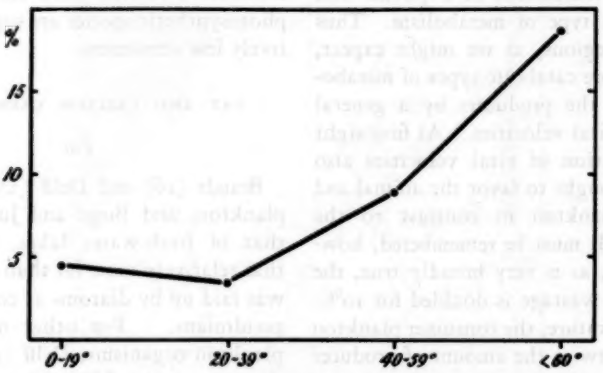

FIG. 5. THE PERCENTAGE OF FAT IN THE DRIED COARSE NET PLANKTON COLLECTED NEAR THE SURFACE AT SEVERAL STATIONS AND EXPRESSED AS THE MEANS OF FOUR ZONES OF LATITUDE

The highest fat values always came from the northern part of the area where the bottom temperatures were lowest, and the negative correlation was always greater in June than in October.

A qualitative difference in fat with latitude and temperature has been indicated for land plants by Ivanoff (56) while Leathes and Raper (63) suggest that fats generally are of a lower melting point at the lower temperatures of high latitudes.

Seasonal variations of fats and carbohydrates for mixed Hensen net catches have been given by Brandt (16), and to

these I add, in Table 2, the monthly mean percentage fat-content of six routine stations which I have regularly investigated in an area between Flamborough Head and the Dogger Bank from 1932 to 1936. The values are also shown as a graph in Fig. 6.

These results show fat production to have reached its highest in late spring and early summer, at a time somewhat after the temperature minimum. Values were comparatively low in the late summer and autumn when peridinians predominate.

There is also an interesting difference between species of diatoms characterizing different seasons. In the North Sea, *Rhizosolenia styliformis* and *Biddulphia sinensis* are autumn forms, while *Coscinodiscus concinnus* occurs more often in the cooler water of spring. The percentage of ether-soluble matter for two of these species taken in similar positions in the same year, but in the spring and autumn respectively, are as follows:

Coscinodiscus concinnus	18.8
Rhizosolenia styliformis	4.1

For *Biddulphia sinensis* the figure is almost the same as for *Rhizosolenia styliformis*.

TABLE 2

Seasonal variation in plankton of fats and carbohydrates

No. of stations dealt with..	16	17	22	20	22	30	30	23	30	29	30	21
Percent ether soluble matter to dry weight at 80°C....	11.7	7.0	9.2	13.0	18.0	15.1	15.2	10.9	12.1	11.1	12.1	14.4
Month.....	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII

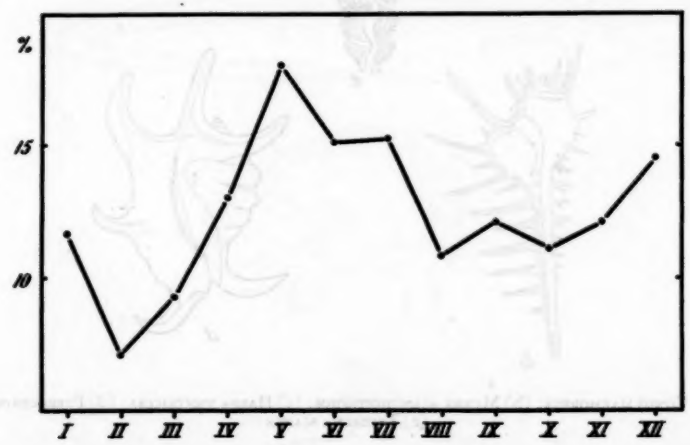

FIG. 6. SEASONAL VARIATION IN THE PERCENTAGE OF FAT TO DRY WEIGHT FOR HENSEN NET PLANKTON CAUGHT NEAR FLAMBOROUGH HEAD

The seasonal differences in the fat-content of diatoms and of mixed Hensen net catches are accompanied not only by differences in radiation, but, according to the work of Atkins (6) and Harvey (43) by parallel differences in the amounts of nutrient salts available for algal reproduction. The work of Graham (40) also suggests that the same parallelism may

occur in the regional variation of the ether-soluble figure for the North Sea area which I have already mentioned. These complications appear to be absent from investigations made by Ahmad (2). Under controlled laboratory conditions this worker found more fat in the colder seasons for cultures of *Nitszchia closterium* grown in modified Miquel's solution.

that lower temperatures facilitate the formation of fat.

Calcium carbonate

One of the most important end-products is calcium carbonate, responsible not only for the relatively considerable skeletons of the Coccolithophoridae, already mentioned as characteristic of the plankton

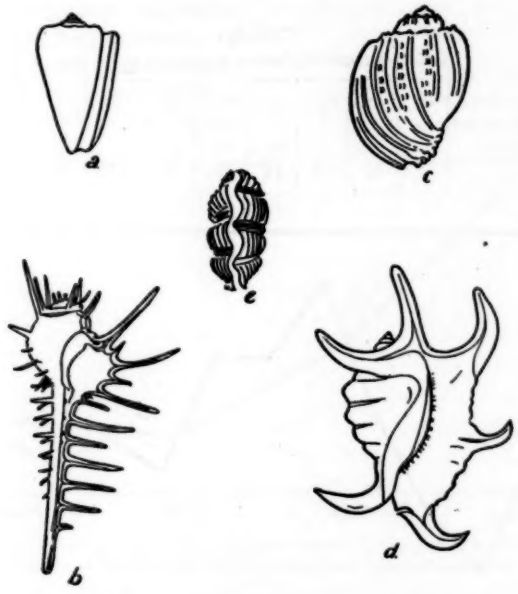

FIG. 7. (a) CONUS MARMOREUS: (b) MUREX ACANTHOSTEPHOS: (c) HARPA VENTRICOSA: (d) PTEROCEROS RUGOSUM: (e) TRIDACNA SCAPHA

Considering pelagic Crustacea, the case of *Calanus finmarchicus* is worthy of note. According to Nicholls (81) this species spends the winter as a stage V copepodite, and it is in this stage that it is fattest, although it must be said that the highest values actually found for this stage were recorded in the summer. Experiments carried out by Geoffrey Smith (111) are of further interest in this connection, his work on the *Cladocera* appearing to show

algae in the warmer parts of the ocean, but also for those of an important group of protozoa, the Foraminifera, and among molluscs, the Pteropoda.

Along the littoral zone between the poles and the equator, the big brown algae are replaced by smaller red forms, among which the species that calcify become more important as the temperature increases, until that massive calcification of certain species known as nullipore

"coral" appears in the sub-tropical zone. In the tropics these are succeeded by the limy masses of the true coral which often make up the entire shore. In this latter habitat are also found a variety of species belonging to the Gastropoda and Lamellibranchiata characterized by the great size and thickness of their shells. Examples of these are the species of the genera *Tridacna*, *Spondylus*, *Murex*, *Harpa*, *Conus*, *Pterocera*, etc. (Fig. 7). Among teleostean fishes, the distribution of the Acanthopterygae—a group recognized by earlier systematists as characterized by bony fin-rays—is mainly tropical and warm temperate. Species inhabiting the tropical

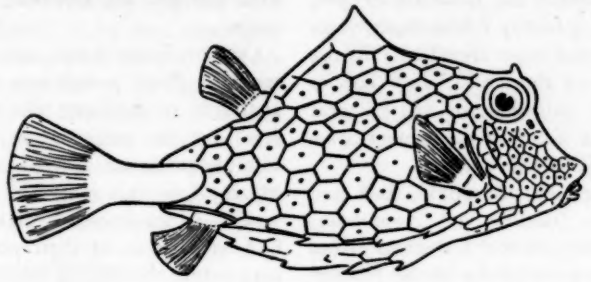

FIG. 8. OSTRACION TURRITUS
(From Day)

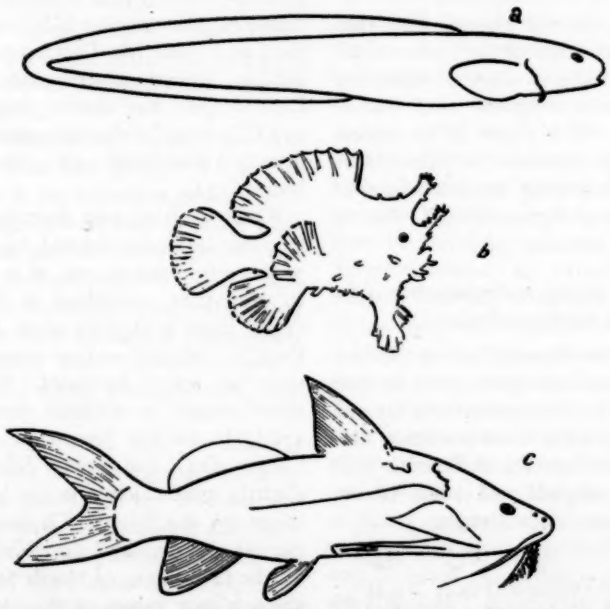

FIG. 9. (a) LYCODES FRIGIDUS (ARCTIC DEEP WATER): (b) PTEROPHRYNE HISTRIO (SARGASSO SEA): (c) SYNODONTIS SCHALL (NILE)

coral coasts are often very heavily ossified, culminating perhaps in forms like those of the family Ostracionidae, where the body is a completely rigid armored box (Fig. 8). Outside the Acanthopterygae, the Siluridae, a family whose fresh-water species are found most abundantly in the warmer parts of the world, show species with heavily ossified heads and pectoral spines such as occur in the genera *Synodontis* and *Schilbe* (Fig. 9).

In the deep sea, Gorgonid, Isid and "star" corals (*Oculina* and *Amphihelia*) present in the Atlantic are absent from adjacent deep parts of the cooler Norwegian Sea (5). In the cool depths of the ocean there is also a general lack of ossification in fishes at all latitudes.

Finally, it may be pointed out that increased calcification of the human skull at lower latitudes is shown when the tropical Negro is compared with that of the European. This matter is the subject of interesting comment by Herodotus (49), when describing the battlefield of Pelusium where Egyptian and Persian dead lay side by side.

The relation of calcium to the formation of fat and calcium carbonate

Work done by Pearsall (91) on diatoms and by Sherman and Quin (107) on rats has suggested a relation between fat and calcium. A similar correspondence also appears on consideration of Brandt's (16) analyses of copepods and some of my unpublished results for diatoms:

	Per cent fat	*Per cent CaO*
North Sea Stn. 7 (Copepoda)	19.23	0.43
North Sea Stn. 4 (Copepoda)	4.59	0.16
Vg.H. Stn. R (*Rhizosolenia styliformis*)	4.1	0.91
Vg.A. Stn. 31 (*Coscinodiscus concinnus*)	18.8	3.38

Clowes (20) considers that the presence of a preponderance of calcium ions at a cell surface favors the formation of fat by throwing the oil-water emulsion at this surface into an oily phase due to the formation of an insoluble soap. Potassium and sodium, however, form soluble soaps.

On the other hand, calcium may be removed from a solution (where it is available to facilitate the formation of fats) by its precipitation as insoluble calcium carbonate. According to Sir John Murray (79) this may take place in two ways. In the first case, plants, absorbing CO_2 as a result of their photosynthesis, may reduce the soluble bicarbonate to the insoluble carbonate. In the second, the union of ammonia and CO_2, resulting from animal metabolism, is thought to produce NH_4CO_3, the resulting CO_3 ions replacing the Ca of a salt like $CaSO_4$ again to form $CaCO_3$. Recent experimental work by Lipman (66) has shown that ammonia and CO_2 actually do unite under the conditions postulated by Murray and Irvine (77).

While we have seen that there is more calcium carbonate formed by living organisms in warmer seas, it is interesting to note that, according to Wattenberg (121), there is slightly more calcium (as CaO) in Atlantic surface water at higher than at lower latitudes. Here, then, there would be slightly more calcium available for fat formation. Similarly, Cooper (22) has found that there is slightly more calcium in the lower water layers of the English Channel, and my published (125) and unpublished results on the fat-content of North Sea plankton show higher values in the deeper water.

All these observations are in accord with the thesis of a direct correspondence between the formation of fat in organisms and the amount of calcium available in solution. They also imply an inverse relation between fatness and calcification

which has been seen to occur. Actually, some of the most heavily calcified organisms known—reef building corals—have been shown by Yonge (132) to contain fat as a food reserve. The amount, however, is likely to be very small and for *Acropora*, obtained from the Red Sea and kindly sent to me by Dr. Cyril Crossland, I have found this content to be less than 1 per cent of the dry weight of the flesh excluding the skeleton. This low percentage is, thus, in accord with all our other observations from warm seas.

DIFFERENTIATION

Living bodies are separated, often obscurely and rather arbitrarily, chiefly by differences of shape into groups of similar individuals called species. The various species are divided by a physiological difference into two groups, the Animals and the Plants.

In the section on vital velocities I have considered these two groups as living at different rates, the animals beginning with a more complex food and working more towards that part of the metabolic cycle where end-products are produced. Here I would add the important consideration that because animals depend upon plants as a food, they must necessarily have a less total food supply available than have plants.

The different vital rate in animals would lead one to expect greater differentiation in the group, and this is indeed the case, for the majority of animal and plant organisms are distinguished by the development in the former of complex excretory, sensory, locomotor, and alimentary organs absent in the latter.

To continue a consideration of differentiation as applied to animals and plants generally it will be interesting to compare the estimated number of species of plants with those of animals. In 1900, Vines (119) made an estimate of the plants then known, the figures of which have been rounded off by Scott (103) in the following way:

Angiosperms	103,000
Gymnosperms	2,500
Vascular cryptogams	3,500
Mosses and liverworts	7,500
Fungi and bacteria	40,000
Lichens	5,500
Algae	14,000
Total	176,000

Now these 176,000 species of plants support all the species of the animal kingdom, of which one sub-class alone—the insects—has been computed at 250,000 by Shipley and McBride (108) at about the same time that the estimate for plants was made. As the metabolic rate of animals is greater than plants, and as their food is less, it is clear that the total bulk of animal tissue must be less than that of plants. Specific differentiation, is therefore, all the more intense in animals. The contrast between animals and plants can then be stated in one way as of greater differentiation at the expense of mass in animals with the attendant circumstances of less food and a greater metabolic rate.

Leaving these general considerations of the two great groups of living organisms, let us turn to the spatial distribution of their marine constituents between the two poles. Gardiner in his book *Coral Reefs and Atolls* (34) says that the total number of plants—algae—on the surface reefs and slopes of any atoll is probably about 150, and he gives the following figures from the "Sealark" Expedition to the Indian Ocean:

	Total	*Surface reef*	*22–33 fthms.*	*36–55 fthms.*
Rhodophyceae	85	53	36	18
Chlorophyceae	36	22	21	16
Phaeophyceae	13	13	3	2
	134	88	60	36

This luxuriance of form is in sharp contrast to the observation of Rudmose-Brown (98) that "10 or 11 species of algae were taken in 10 fathoms from a single bay in the South Orkneys," or to the result of Holmson's account of the marine and non-marine algae of Spitzbergen (54) where only 62 species were found.

Hensen (46) in his account of the German Plankton Expedition of 1889 gives the numbers and forms of diatoms found at twelve stations on the course of the "National" between July 29th and August 4th. Six of these stations were in the Labrador Current and six a little further to the south in the Florida Stream. In the Deutschland being relatively close to land during this part of her course.

The Dinophysoidea of the eastern tropical Pacific revealed themselves in collections made by Kofoid and Skogsberg (60) as 132 species out of 198 recognized by the authors as constituting the family. In her *Dinoflagellates of Northern Seas*, Dr. Lebour (64) describes 22 species of this family as inhabiting North Temperate to Boreal-Arctic seas. For a region still further north, Meunier (73) notes only 6 species for the same family.

In the animal kingdom there are some recent surveys of Foraminifera of the Southern Hemisphere by Heron-Allen and

TABLE 3

Relation of number and species of Coccolithophoridae to latitude (Atlantic Ocean)

Approximate latitude	40–45 to 40–25 N.	40–25 to 40–0 N.	30–45 to 30–25 N.	30–05 to 10–45 N.	10–15 to 0–30 N.	0–15N. to 0–30S.	0–45 to 20–20 S.	20–40 to 30–35 S.	30–55 S.
Temperature range (0–100 metres)	11–15	14–18	15.5–21	19–26	15.5–27	19–26	21–26	15–20	5.5–9
Number of species	4	5	8	10	10	11	12	12	7
Number of individuals	638	1191	1418	454	168	990	571	1122	2174

former area there were 40 forms, but in the latter 60.

Perhaps a better example of the relation of number of species of plankton algae to latitude is afforded by Lohmann's (68) centrifuged samples. These were obtained in the Atlantic while on the "Deutschland." In Table 3 I give an extract from his table showing the number and species of Coccolithophoridae occurring per litre of water between the surface and two-hundred metres, together with the approximate latitudes of his stations.

Here the smaller numbers are met with at the most northerly and southerly stations. Though there are more species in the south than actually at the equator it is probable that this is due to the Earland (50). These surveys show that 419 species were taken at 56 stations in the neighborhood of the Falkland Islands and only 345 at 90 stations near South Georgia. The Falkland Islands lie between 51° and 53°S., in the Sub-antarctic region. They are outside the limit of the pack-ice and the neighboring sea water is of Pacific origin. South Georgia, on the other hand, is surrounded by northward flowing cold antarctic water and is in the pack-ice area, though it lies only a little further south—between 54° and 55°S.

For the Metazoa, Hentschel (48) gives a table of sponge species distribution in the following form:

Arctic	*Tropical Atlantic (30 N.–30 S.)*	*Antarctic*
379	428	235

With more regional sub-division, Hertmeyer (42) gives a similar table for the Tunicata:

Arctic	*Sub-Arctic*	*Tropical*	*Sub-Antarctic*	*Antarctic*
103	433	619	223	42

Concerning the Crustacea, interesting data have been published by Hjort (53) who gives the number of species of Crustacea, chiefly Copepoda, at different depths and temperatures for five stations made in the Atlantic by the "Michael Sars." Two of the stations (50 and 63) were in the Sargasso Sea, one (80) off the Newfoundland Banks, one (90) off the south of Ireland and one (113) in the Norwegian Sea north of the Wyville Thomson Ridge. An abstract of these data is reproduced in Table 4, the figures in brackets, following the number of species, being the temperature range in degrees centigrade for the corresponding depth.

There is clearly a general diminution of species as the temperature falls in the parts of the Atlantic covered by these investigations. In the same connection let us compare the species of copepod found by Aurivillius (8) at a number of stations in the sea between Norway and Jan Mayen with those found by Farran (32) at a few stations near one position in the Bay of Biscay. In the first case there were 16 species, in the second, 84. The records of the *Calanoida* are another interesting commentary on the differentiation into species in warmer habitats. In Sars' work on the Crustacea of Norway (101) he gives the number of species as 67, but more recently Sewell (105), in the results of a very thorough investigation of the same group for the Indian Ocean, has described 377 species.

Fishes are well known to have very many more species in the warmer waters of the world (see for instance Norman, 84). The following list of littoral genera and species of fish from different localities which I have taken from Ekman (29) shows the extent of differentiation in tropical and semi-tropical habitats:

TABLE 4

Number of species of Crustacea, chiefly Copepoda, at different depths and temperatures

(After Hjort)

DEPTH	STN. 50	STN. 63	STN. 80	STN. 92	STN. 113
0 to 2–300 m.	22 (17.7 to 20.3)	25 (16.7 to 27.3)	16 (7.6 to 11.8)	18 (11 to 16.5)	21 (8.3 to 11.6)
2–300 to 500 m.	22 (13.7 to 17.7)	32 (13.8 to 16.7)	27 (4.6 to 7.6)	12 (10 to 11)	18 (1.1 to 8.3)
500 to 1000 m.	51 (9.7 to 13.7)	27 (6 to 13.8)	34 (3.3 to 4.6)	33 (8.6 to 10.2)	11 (0.5 to 1.1)

Arctic and Sub-arctic	64 species
North Sea	68 genera
Mediterranean	144 genera
Red Sea	191 genera
West Indies	299 genera
Tropical W. America	256 genera
South Japan	658 species
North Japan (total)	134 species
Australia	344 genera
New Zealand	108 genera

The diminution of species as one goes north in the Northern Hemisphere is well shown in the proportions of the different food fishes caught in the different statistical areas into which the Ministry of

Agriculture and Fisheries divide their annual Sea Fisheries statistics. More species go to make up the returns from southern areas than from those further north.

On land where the habitats are so much less uniform than the sea it is not possible to compare wide areas with respect to the temperature gradient and differentiation. For a stretch of Africa there are, however, censuses of the number of species of forest trees carried out by the Imperial Forestry Institute of Oxford and published in the 1934 report. I give the figures in order of latitude:

Union of South Africa	455
Southern Rhodesia	883
Northern Rhodesia	972
Uganda	1371

The number of species identified in these areas diminishes with latitude and it seems likely that there is no climatic difference that would be as important as temperature. If we compare Uganda with another tropical district, Nigeria, where the rainfall is heavier, we get 1371 compared with 1240. Here rainfall which appears to be the important factor in the formation of tropical forests does not appear to have had much effect on the differentiation into species.

TABLE 5

Groups of land animals in the tropics in which the greatest differentiation into species appears to have occurred

(After Hesse)

Land snails	*Tailless batrachians*
148 Scandinavia	21 Europe
193 Japan	Over 50 British Guiana
463 Jamaica	
614 Cuba	*Snakes*
80 Tasmania	31 Europe
	38 Trinidad
Butterflies	3 Tasmania
4560 S. America	22 Victoria
716 Europe and Asia N. Himalayas	42 New South Wales
	70 Queensland
400 Europe	
	Birds
Ants	257 Europe
2888 Tropics	580 Borneo
1055 Temperate zones	

Hesse (51) has given several groups of land animals in which the greatest differentiation into species appears to have taken place in the tropics. These are shown in Table 5.

MASS AND DIFFERENTIATION

In view of the tendency for specific differentiation to decrease with latitude in the manner already discussed, I think it relevant to commence this section by inviting a consideration of the total fishery yields, shown in Table 6, for the principal countries of the world and divided roughly into areas lying between 30°N.–30°S., north of 30°N., and south of 30°S. These yields, together with those of whale oil, are all expressed in 1,000's of tons and are taken from Schott (102), le Courbe (65) and the *Bulletin Statistique* of the International Council for the Exploration of the Sea (18).

The figures in Table 6 show clearly the inferiority in yield for the tropical area compared with those both north and south of it.

For the Mediterranean I have pointed out (126) that there is an increase in price of fish from west to east which suggests that the fisheries of the western part are more productive than those of the east.

My own work (127) and that of Natterer (80) and Pereira (93) show higher values for estimates of organic matter in the sea water of the western Mediterranean. Thomsen (116) has shown a similar distribution for phosphates. Moreover, the sea temperatures increase eastwards along the Mediterranean. Sparck (112) in his work on the Mediter-

ranean produces values for the grammes per square metre of bottom fauna, which, while showing the Mediterranean to be poorer than northern seas, also indicates that it is more fertile at its western end.

	Grms. per m²
East of Italy	6
Bay of Algiers	18.7
South-east of Portugal	166.4
North Europe	300–400
Greenland	100

greater as we go north through the areas in the continental slope, but the catch per hundred hours fishing progressively increases and the number of species diminishes.

In Fig. 10 I have illustrated the catch per hundred hours fishing for the Iceland and North Sea grounds by circles whose areas are proportional to this catch. The segments represent the percentage by weight of the components over one per

TABLE 6

World yields in thousands of tons

	FISHERY YIELDS		WHALE OIL	TOTAL
Japan	4635.0			
U. S. A. Alaska and Canada	1983.0	10028.3	14.6	10042.9
N. W. Europe	3243.0			
Mediterranean	167.3			
Mexico	6.3			
Hawaii	4.5			
S. India	141.5			
French Indo-China	160.0			
Straits Settlements	65.1	428.5	9.8	438.3
Figi	1.4			
Peru	4.0			
Union of South Africa	15.0			
Australia	30.7			
Chile	19.9	39.9	4092.7	4132.6
New Zealand	20.0			

In the Mediterranean, therefore, it would appear that we have a case in which conditions are similar to the general latitude gradient.

While the amount of fish landed within different regions generally decreases towards the warmer parts, it is in these latter areas that the greater number of species tend to be landed. The areas set up for the enumerations made in the Sea Fishery returns for England and Wales may be usefully examined in this connection. The figures for 1931, given in Table 7, show that not only is the gross yield

cent, a residual segment containing a figure showing the number of species and categories in the returns that are individually less than one per cent. While the much smaller North Sea catch is doubtless due in part to the longer and more intensive fishing this area has undergone, the greater differentention of the catch, so well shown in the figure, is a qualitative difference of wider significance. The example is, in short, in conformity with the other cases dealt with in this section and in which mass appears to be inversely related to differentiation.

TABLE 7

Gross yield, catch per hundred hours fishing, and number of species in different areas in the continental slope

REGION		YIELD IN CWTS.	CWTS. PER 100 HOURS FISHING	SPECIES IN RETURNS
Bear Island and Spitzbergen	II B	924,831	2,115	12
Iceland	V A	3,382,343	893	19
Faroe	V B	957,468	457	21
Rockall	VI B	25,025	355	20
W. of Scotland	VI A	880,740	293	28
W. of Ireland	VII B and C	194,574	211	28
S. of Ireland	VII G and K	665,396	188	28
Portugal and Morocco	XIX	1,116	122	14

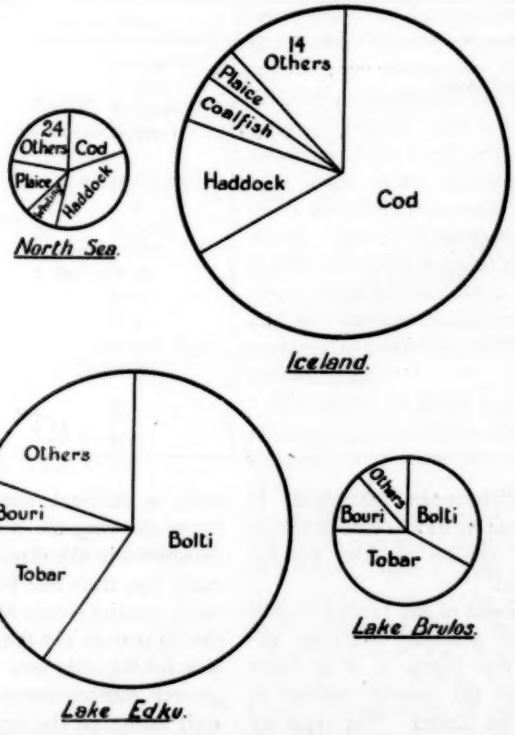

FIG. 10. CATCH PER HUNDRED HOURS FISHING FOR ICELAND AND NORTH SEA GROUNDS AND FOR TWO EGYPTIAN LAKES

Above: circles proportional to the catch per hundred hours 1st class steam trawling in the North Sea and Iceland areas for 1931. *Below:* circles proportional to the mean catch per hectare of two Egyptian lakes for the mean yield of nine post-war years. In all the figures the proportionate weights of the constituent species are shown by the segments.

The relation between mass and differentiation on the one hand and food and temperature on the other, is well shown by the fishery yield of the shallow lakes in the Nile Delta (Fig. 11). Of these lakes, Mariut and Edku in the western delta receive more water and are slightly cooler than those in the east (Wimpenny,

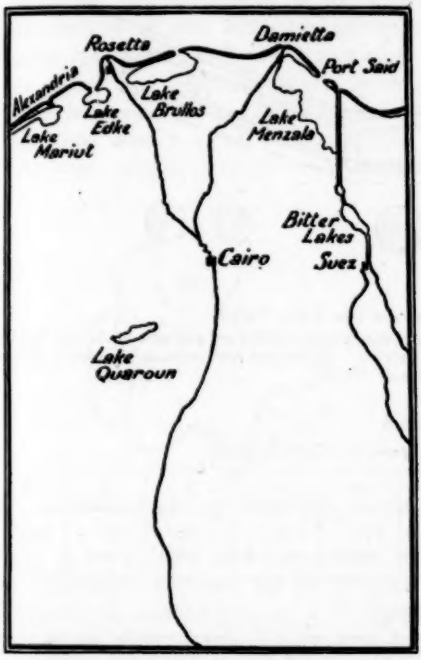

FIG. 11. MAP OF EGYPT SHOWING THE POSITION OF THE DELTA LAKES

128). Their yields and the number of species common enough to enter the market categories are shown in the following list:

Lake	Kgms. per hectare	Species in returns
Mariut	141	9
Edku	279	11
Brullos	60	21
Menzala	64	21

The superior yield and lower differentiation of the cooler lakes with the better food supply is very marked, and in Fig. 10 I have contrasted the extreme cases of Brullos and Edku in the same manner that has been applied to the fisheries of Iceland and the North Sea.

The yield and differentiation into component species for a series of ponds of a Cairo fish farm are shown in Fig. 12 and the areas of the ponds together with the yields per hundred square metres are given in Table 8.

In these ponds the sluices were of the same size and the smaller ponds would therefore have the better food supply per unit area. It is these smaller ponds that furnished the larger yields and whose communities were usually the more simple. The diagram shows that simple communities were also associated with low yield, but in these cases a considerable proportion of the community was made up of predatory species, probably in the process of extinguishing their own food supply.

Further cases bearing on mass and differentiation may be taken from ecological studies on crustacean communities. From work on the copepod fauna of eight rock pools Fraser (33) has given the number of species present and the corresponding densities for each pool. His results are shown in Table 9.

It will be seen that the largest numbers occurred in the pools with only two or three species. The zooplankton of Lake Qarun, which I investigated at fortnightly periods throughout a year (130), was composed of three species of Crustacea. In the cold season, when the catch was far more numerous and the individuals larger, there were virtually only two species present.

Finally, mention must be made of

parasites, which, taking advantage of an easy and abundant food supply, achieve a relatively large size accompanied by loss of differentiation. A curious example of this is *Hemioniscus balanus*. The female of this species (Fig. 13) is found on *Balanus balanoides* and is only recognized as an isopod by the head and first four thoracic segments, the rest of the animal having grown into enormous featureless lobes.

Both Ekman (29) and Hesse (51) refer to the inverse relation between the number of species and the number of individual in a habitat. The former attributes to Thienemann (115) the fundamental ecological principle that the more extreme, specialized and far from the optimum of the majority of organisms is the habitat, the poorer in species but the richer in numbers is the community which inhabits it.

This inverse relation between species and numbers, which appears to be widespread, is particularly well shown in the relations marine organisms of the tropics

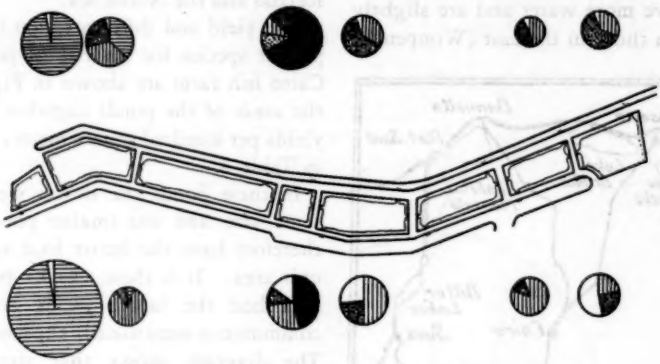

FIG. 12. PLAN OF THE BARRAGE FISH FARM, CAIRO

Above, are circles showing the proportions by weight of the different species per unit area of the corresponding ponds: below, numbers are treated the same way as weights. Horizontal lines indicate "Labees", vertical lines "Bolti", dashes "Bouri", dots "Laffash", and all black "Tobar".

TABLE 8

Areas and yields of a series of ponds of a Cairo fish farm

POND	A	B	C	D	E	F	G	H
Area	500	1,560	2,090	650	1,575	1,380	956	1,424
Kgms. per 1000 m^3	14.7	9.7	4.7	13.8	6.8	6.1	2.7	5.4

TABLE 9

Copepod fauna of eight rock pools

POOL	1	2	3	4	5	6	7	8
Species	12	16	6	10	5	2	3	2
Number of copepods per litre	3	30.4	24	41.2	100	12.3	1,769	807

bear to those of cooler areas, and in this section I have attempted to show an extension of the relation through numbers to mass. I think we should be cautious, however, before going so far as to define the habitat of the species-poor but numerically rich community of cooler areas "as extreme" and "specialized" in this connection. Particularly in the plankton communities all this extremity and specialization means is lower temperature and richer food supplies. While in the Cairo fish ponds it has been suggested that food supply alone was associated with the simple massive community,

FIG. 13. ADULT FEMALE OF HEMIONICUS BALANUS

there is little doubt that temperature is an important condition for an internal optimum of assimilation, as it is clear that at its higher levels it must tend to produce an increased vital velocity resulting in differentiation, speciation and a more wasteful use of the available food-supply. Nevertheless the effect of temperature on organisms can seldom be separated from external food supply. In these circumstances I am inclined to replace Thienemann's fundamental principle by a generalization in the following terms: The numbers and mass of organisms tend to vary inversely with the number of species living in any given habitat. Where the habitat conditions remain otherwise the same, a higher temperature and a lower food supply favors specific differentiation and a reduction of the numbers and total mass of organisms.

INDIVIDUAL SIZE

I want to suggest in this section that, for the bulk but not for all animal forms, there is a tendency for size to increase with latitude. This tendency is also shared by the peridinians. Marine diatoms, however, together with certain animals form a minority group presenting us with the reverse of this phenomenon.

Dealing first with organisms which show an increase of size with latitude, cases of increased individual size within the same species of Foraminifera have been given by Rhumbler (96), while Popoff (95) has shown a decrease in size with rising temperature for the ciliate *Stylonichia mytilus*. For *Cyanea capillata* we have Mayer's (72) measurements showing the superior size of the varieties of this species coming from colder northern waters; and for two other species of medusae, *Aglantha digitalis* and *Phialidium hemisphaericum*, Russell (99) has published measurements showing that the largest individuals originate in the coldest season. Examples from pelagic marine Copepoda given by Steuer (113) may be reinforced by those of Bogorov (15) on the superior length and weight for individuals of *Calanus hyperboreus* and *C. finmarchicus* taken in higher latitudes. In Fig. 14 I have superimposed figures giving the size of some common calanid and euphausid species upon charts showing the limits of their distribution as established by Mackintosh (71). Here again it is apparent that the sister species in higher latitudes are superior in size. The same conclusion is reached by an inspection of the sizes and limits of distribution for the species of *Sagitta* (Ritter-Zahoney, 97) and

the appendiculate tunicate *Oikopleura* (Lohmann, 69).

Among fish, the herring, anchovy (De Buen, 26), hake (Hickling, 52; Belloc, 12) and Norway haddock can be quoted as species in which the largest individuals come from the highest latitudes. In the case of the herring, there is an exceptionally small race coming from the shallow waters of the White Sea, which may well belong to the minority group for reasons given below. Considering sister ranges into much higher latitudes than the Sperm Whale, *Physeter macropthalmus*, whose length is given by Silversan (109) as 50–60 feet. There is also the case of the tropical dugongs and manatees, creatures measuring about 8 feet compared with the recently extinct and nearly related *Rhytina stelleri*, which lived in the Arctic and measured 20–30 feet. Among seals, again the largest member of the order, *Macrorhinus leoninos*, comes from the Antarctic polar regions.

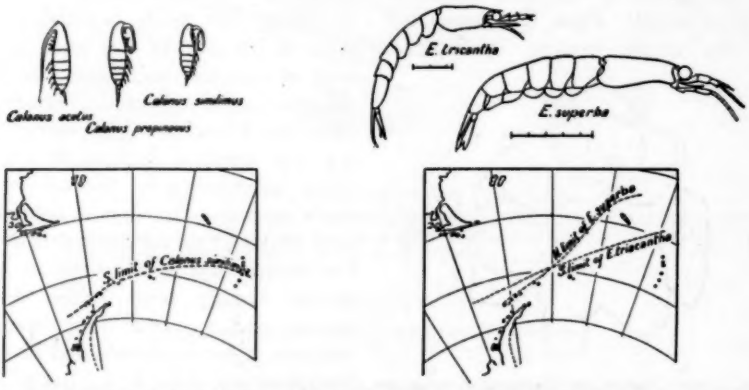

FIG. 14. FIGURES SHOWING CERTAIN SPECIES OF CALANUS AND EUPHAUSIA AND THEIR DISTRIBUTION IN THE ANTARCTIC

species, we have the case of *Cyclone microdon*, which lives in cooler water, and is superior in size to *C. signata* (Hjort, 53). A perusal of Hjort's observations gives a number of other similar cases for oceanic fishes.

Measurements of sea birds given by Alexander (3) show a gradient of size increasing with latitude for the distribution of Penguins, and, using breeding grounds as loci of distribution, for Albatrosses and the seagull genus *Larus*. For marine mammals, I may point out the superior size of *Balaenoptera sibbaldi*, (maximum length, 93 feet, 6 inches, given by Mackintosh and Wheeler, 70) which

In respect of land animals Hesse (51) has called attention to Bergmann's principle, and gives a convincing list of warm-blooded animals, among which, both for related species and for individuals of the same species, a greater size is attained in the colder regions of the area of distribution concerned.

It may now be considered how, in these large and varied sections of the animal kingdom, the circumstance of lower temperature may be connected with an increase of size. Discussing marine animals, Harvey (45) has suggested that the same amount of organic matter could be more economically supported in cold than in

warm habitats. While it has also to be borne in mind that animals generally have more on which to live in colder seas, work has been done which minimizes the importance of food, in so far as its external availability is concerned. Coker (21), working on *Cyclops*, came to the conclusion that low temperature and not food was primarily responsible for increase of size. In this case, the suggestion of an internal optimum for assimilation at a lower temperature is an obvious one to make. Another explanation of the cause of greater size at lower temperatures, has been put forward by Hesse (51) who points out that the onset of maturity is retarded and a longer time is available for somatic growth in these conditions. Lastly, as has been mentioned above, Hesse (51) has adduced examples from among warm-blooded animals, which appear to follow Bergmann's principle (13). This principle contends that larger size is a device to conserve heat, as increase of size in bodies of the same shape decreases the relative radiating surface. It will be understood in this connection, that, while mass increases as the cube of the linear dimension, the surface increases only as the square. Bergmann's principle, it should be noted, does not cover the many instances of cold-blooded animals which have just been dealt with.

A final order of organisms showing this tendency for an increase of size with lower temperature is that of the peridinians. The work of Wesenberg-Lund (112), Bachmann (9), List (67), and Pearsall (92) has shown that the fresh-water *Ceratium hirundinella* decreases in size as the temperature rises. For several species of marine *Ceratium* collected in the South Pacific Ocean, Steeman-Nielson (82) has found the same relation to obtain. The size changes of *Ceratium hirundinella* have been explained by Pearsall (92) as the result of unusually rapid cell-wall hardening at higher temperatures. According to Pearsall there are two agencies which determine cell size in peridinians, one being wall-hardening and the other cell-turgor, due to the rate of water absorption. Size is the resultant of these two forces, and at higher temperatures, when wall-hardening goes on at a relatively greater rate than cell-turgor, the size of the cell is restricted.

In short, it seems that in peridinians, as in the other forms of this majority group we have now considered, the relative increase of the respiratory function at higher temperatures results in less assimilation and smaller size.

Now let us turn to the minority group in which the larger species and individuals are found in warmer habitats. In the sea, the most striking examples are derived from the tropical coasts. Here are found massive gastropods and the huge lamellibranch *Tridacna*, replaced towards the poles by smaller molluscs. In a general statement about tubularian hydroids Allmann (1) says "... it may perhaps be asserted that the largest hydroid forms are as a rule confined to the warmer seas, while those of temperate and colder latitudes consist for the most part of humbler and less conspicuous species." According to Parker and Haswell (90) the Actiniaria are also larger in the tropics. An examination of the size of various species of *Balanus* given by Darwin (24) shows that, here too, the largest species, *B. ajax* and *B. psittacus*, both 3.5 inches in diameter are tropical or sub-tropical. While ascidians and echinoderms as a whole appear to belong to the majority group, it may be noticed that Moore (76) has shown an increase in the diameter of the individuals of *Echinus miliaris* for samples taken southwards from Millport through Port Erin to Plymouth.

The position of fishes is somewhat anomalous in respect of the size relation under discussion. Although we have seen individuals of the same species and sister species behaving as if they followed a law which increased their size at lower temperatures, yet, when lists of all the fish over 1,000 pounds in weight, mentioned in Norman and Fraser's book (83), are set down for warm and cold areas, it will be seen that there are six in the former habitat and only one in the latter.

Warm areas	*Cold areas*
Tunnies	Sturgeons
Spear-fish	
Sail-fish	
Sun-fish	
Sea-devils	
Hammer-heads	

In addition, the largest fish known—*Rhineodon typicus*—is a warm-water form. Discounting the fact that there are more species of fish in the warmer areas, it still appears that these bigger fish favor higher temperatures. We may perhaps search for a clue to their behavior by observing that these giants are all either littoral or pelagic forms and not representative of all the fish communities.

Of terrestrial animals, insects (with the exception of some bumble bees), amphibia, and reptiles all fall into the minority group. In addition, I would add, from among the mammals, bats.

In the case of terrestrial animals, and those which live in shallow coastal water, or near the surface of the sea, I think the diminished size at higher latitudes is most likely to be caused by intermittent growth due to the longer and deeper seasonal fall in temperature. For land animals, the increasing duration and severity of the temperature depression results in progressively longer periods of hibernation for reptiles, amphibians and some mammals (e.g. bats) as the poles are approached. In insects, the period of pupation is increased. Seasonal diminution of organic production in coastal and superficial areas of the sea may exert a similar effect, reducing the time possible for assimilation to a greater and greater degree as the poles are approached. This effect would be especially marked on organisms with a life of several years, on those unable to pursue their prey (i.e. in particular sedentary forms), or those whose natural food supply is specially affected by seasonal falls of temperature. In the explanation just advanced, there can be little question of size differences being governed by temperature at different latitudes, as the postulated differences in the external food supply robs the conditions for comparison of any uniformity.

To this minority group must also be added certain plants—the pelagic diatoms. Taking the species dealt with in Lebour's *Plankton Diatoms of Northern Seas* (129), it appears that in nineteen genera spread over a wide area and containing species living in warmer and colder habitats, there are thirteen in which the smallest species were found in the colder part of the generic range.

Marine diatoms find their optimum conditions for growth in numbers in the cooler areas, where the sea affords them a better nutrient medium. The explanation of their greater individual size as being due to better external conditions for assimilation seems, therefore, to be excluded. I have made some speculations on this matter in an earlier paper on the size of diatoms (129) which I may here re-state and extend. The cell-walls of cold-water diatoms are thicker than those from the tropics, consequently a few divisions by internal sliding growth would produce a narrower cell than the same number for a thin-walled individual. Moreover, surface tension effects might cause the newly

formed thin-walled auxospore bud to arise at a greater size in warm water. In this connection it should be noted as incidental to the work of Gross (41) that for four species in which auxospore size has been given at different seasons, it was greatest in the warm season for two, showed no difference in one, and was greatest in the cold season for the other. Another possibility is based on the work of Barker (10) which suggests that the effect of rising temperatures may be to increase respiration at a greater rate than photosynthesis. In these circumstances, it seems possible that cells with a relatively high surface-volume ratio (i.e. small cells) might be more rapidly brought to a lethal condition by a rise in temperature than would the larger ones. Larger cells would in fact be favored in warmer seas.

To sum up, although pelagic diatoms resemble some animals in being larger in warmer seas, it is not likely that this resemblance is attributable to the same cause.

SEX

Work on Mendelian inheritance has shown that the production of special chromosomes, or of two kinds of chromosomes and the machinery of reduction division, ensures the production of equal numbers of male and female individuals at fertilization. While this genotypic equality often results in the population of a species of all ages being equally distributed between males and females, it may be subsequently modified by selective mortality or by external causes in such a way as to destroy this balance. A general discussion of cases of this sort has been presented by Goldschmidt (37) and Crew (23), while Geddes and Thompson (35 and 36) have seen in this balance of the sexes a metabolic poise in which maleness is nearer the breakdown or katabolic side and femaleness nearer the anabolic or assimilative side.

If Geddes and Thompson's theory is correct, the effect of increasing temperature might be to increase the ratio of respiration to assimilation towards the upper end of an organism's range of tolerance, and so to produce that relatively katabolic condition they associate with maleness.

However this may be, I have thought it useful to discuss next certain special cases in which I consider temperature likely to bear a significant relation to the sex ratio.

Plants

The alga, *Chara crinita*, and the flowering plant, *Stratiotes aloides*, have been shown by Ernst (30) and Wesenberg Lund (123) to produce females only at the northern and colder limits of their distribution.

A coelenterate

The fresh-water medusa, *Craspedacusta sowerbyi* (Fig. 15, reproduced by kind permission of Professor Fernandus Payne), was first recorded by Lankester (62) from a lily pond in Regents Park. The temperature of the pond lay between 25°C. and 30°C. and all the individuals seen were males. Since then it has frequently been recorded in Europe, mainly from aquaria, whither it is suspected of having been introduced with tropical organisms. It has, however, occurred "wild" in a few localities which we may now proceed to examine.

In September, 1929, the species was found in the Exeter Ship Canal (Vallentin, 117) where the temperature was 18°C.–22°C. All the individuals found were males. More recently Tattersall (114) reported the occurrence of the medusae in a reservoir attached to a South Wales colliery. Jenkins (58) in a detailed report of this occurrence showed that the me-

dusae were found from July to September at temperatures between 20°C. and 22°C. Though these temperatures are slightly higher than those at which the medusae were able to make their appearance in the Exeter Ship Canal, it is likely that the South Wales reservoir is a much colder habitat, taking the year as a whole, as its water supply is derived from the neighboring mountains. Bearing this in mind, it is interesting to note that Jenkins finds "All the medusae without exception were females."

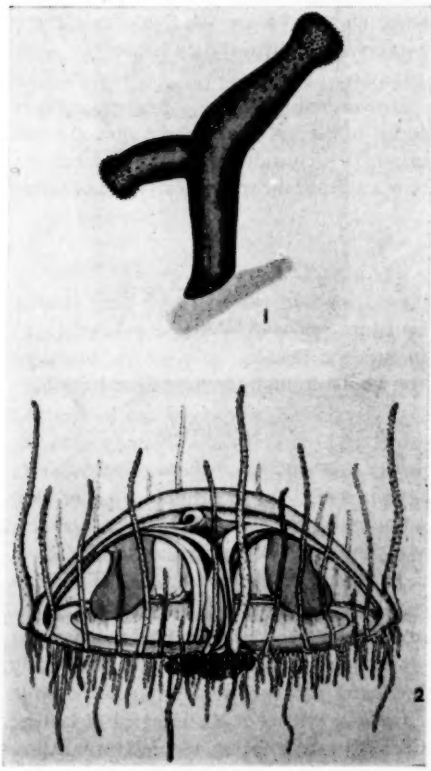

FIG. 15. CRASPEDACUSTA SOWERBYI POLYP ABOVE. FEMALE MEDUSA BELOW (From Payne)

C. sowerbyi has been reported frequently in America, but up to the time of Payne's (88) observations during 1918 in Boss Lake, Indiana, all the occurrences, both in Europe and America, had been males found in aquaria or warm climates. But in Boss Lake all the medusae were females, and the water was "very cold". In a later paper Payne (89) recorded the occurrence of males and females together in the Kentucky River on September 12th, 1925. Since Payne's observations, the medusae have been seen in September, 1933, near Ann Arbor, Michigan, by Woodhead (131). At this most northerly recorded occurrence in the United States "as far as we have been able to determine all individuals were female". In June, 1934, three mature medusae were found at Horseshoe Lake, Quebec Province, in Latitude 46°N. and Longitude 74°25'W. This is the most northerly record yet made for America. Fantham and Porter (31) who reported this occurrence and also another near Rouses Point, New York State, in Latitude 44°58'N. and Longitude 74°25'W. say that all the individuals from both stations were females. The most southerly record from the United States is an old reservoir at Monroe, Louisiana. Here Viosca and Burkinroad (120) record all males, as also does Smith (110) for a habitat in Panama.

Considering the fact that almost always the sex is uniform for each occasion on which the species is found, Payne (89) has suggested that this may be due either to environment or to the fact that each settlement has been due to one introduced hydroid which would be of one sex. On the whole he thought the latter explanation more probable. In the records just presented, however, it has been shown for the United States that females alone have been found in the three northernmost habitats, usually males alone in the central and southern states and that it was

in the central part of the environmental range that both males and females were found together. Moreover, the only record of females from Britain is from a habitat likely to have been exposed to cold influences more than any other. These circumstances do not present a picture such as one would expect to find if the sex of each colony had been determined by the chance introduction of hydroids equally likely to be of one sex or the other. It seems more probable to me that the sex found is an effect of the environment either upon the hydroid or medusoid persons of the species.

If this is so an investigation into whether the environment could operate directly upon the chromosomal machinery, or whether a selective mortality might be involved, would form suitable aims for a laboratory experiment upon this organism. The most obvious environmental factor is, of course, temperature.

Crustacea

Limnadia lenticularis has not been known to produce males in any number (Brehm, 17), but males are in the majority in collections not only of the genus *Limnadia* but also of the genera *Lepidura* and *Apus* made in Africa. *Daphnia pulex* (Olofsson, 85), *Cypridopsis newtoni* (Moniez, 75), *Cypris puberoides* (Vavra, 118), and *Calanus finmarchicus* (Bogorov, 15) have all been shown to have a relative preponderance of females towards the colder limit of their range. Such facts as are known of the distribution by sex for *Rhincalanus gigas* as a result of the work of Ottestad (87), Ruud (100), and Ommanney (86) suggest that this species behaves in a similar way (Fig. 16).

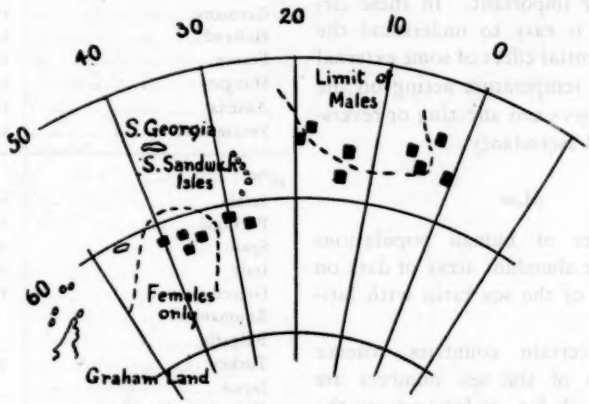

FIG. 16. THE DISTRIBUTION OF RHINCALANUS GRANDIS. "VIKINGEN" STATIONS 1929–30

Insects

Seiler (104) has shown that the effect of increasing the temperature at which the maturation divisions take place increases the proportion of eggs in which the X chromosome is extruded into the polar body and so increases the proportion of males. Seiler's results may be tabulated in the following way:

Temperature (Centigrade)	X chromosome in egg	X chromosome extruded	Sex ratio ♀	♂
3.5	48	31	155	100
18.0	61	45	136	100
35.0–37.0	58	84	62	100

The frog

Goldschmidt (37) quotes experiments of Hertwig and Witschi in which rearing at higher temperatures produced a population predominantly, and in some cases entirely, male. According to Goldschmidt every bisexual individual possesses hormones which can call forth one or the other sex. The sex determining substances act in proportion to their concentration and the times at which they reach their maximum concentrations are obviously very important. In these circumstances it is easy to understand the possible differential effect of some external factor such as temperature acting on the two sex hormones and affecting or reversing the normal ascendancy.

Man

The censuses of human populations show the most abundant array of data on the alteration of the sex ratio with latitude.

Excluding certain countries whence census reports of the sex numbers are difficult to vouch for, as for instance the Anglo-Egyptian Sudan or the Straits Settlements and the Malay States, where there is an unusual distortion of the natural sex ratio due to a large population of immigrants, there is given, in Table 10, a list of 39 populations, set out roughly in order of latitude. It will be seen that in all the populations cited north of Latitude 45°N., whether subject to the mortality of the Great War or not, there were more females than males. Of the ten countries between 45°N. and 35°N., females exceeded males in six countries, and one of them—Spain—is a country which suffered no mortality of males due to the War. Finally, for the thirteen countries included in the zone between 35°N. and 35°S., only three, and these not materially

TABLE 10

Sex ratio and latitude

COUNTRY OR POPULATION	FEMALES PER HUNDRED MALES	CENSUS DATE
Greenland Eskimos	109	
Iceland	105	1920
Finland	103	1920
Norway	105	1920
Sweden	104	1926
Russia	107	1928
Denmark	104	1921
Poland	107	1921
England	109	1931
Germany	107	1924
Holland	101	1920
France	108	1926
Hungary	106	1920
Austria	108	—
Switzerland	107	1930
45°N.		
Serbia	104	1921
Portugal	111	1920
Spain	103	1930
Italy	104	1931
Greece	103	1921
Roumania	98.5	1919
Bulgaria	99.5	1927
Turkey	107	1927
Japan	98	1926
U. S. A. (whites)	96	1920
35°N.		
Mexico	105	1921
Egypt	99.5	1917
India	95	1911
Ceylon	89	1911
Siam	100	1919–20
Columbia	107	1918
0°		
Brazil	98	1920
New Guinea	55	1921
Paraguay	78	1921
Uruguay	82	1926
Chile	101	1920
Union of South Africa	94	1921
Australia	97	1921
35°S.		
New Zealand (excluding Maoris)	96	1926

involved in the Great War, show an excess of females.

While there is a lack of regular graduation by latitude (particularly for the tropical and semitropical regions) in the list that has just been given, there is some reason to believe that this may be partly explained as the effect of mountains. To show this effect I give below a list of the numbers of females per hundred males for a series of eleven countries whose populations live mainly near sea-level:

Finland	103
Denmark	104
Poland	107
Holland	101
Roumania	98.5
Bulgaria	99.5
Egypt	99.5
India	95.1
Brazil	98
Paraguay	78
Uraguay	82

This list clearly forms a much smoother series than the earlier one.

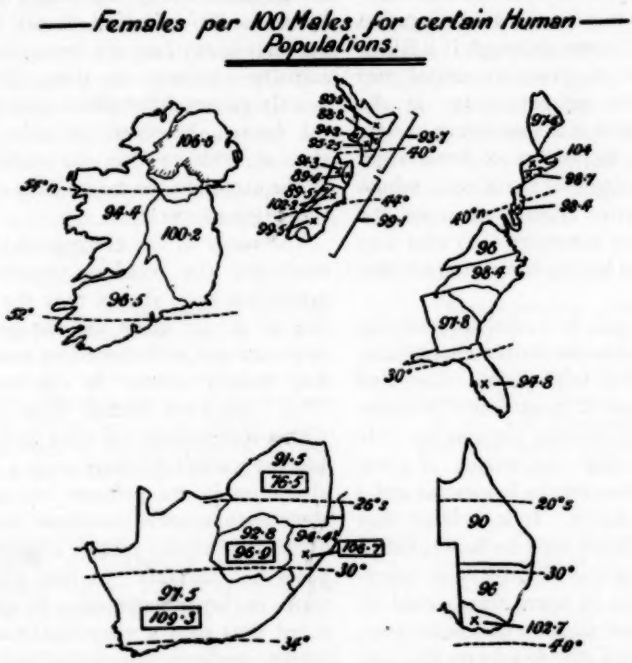

FIG. 17. FEMALES PER 100 MALES FOR VARIOUS HUMAN POPULATIONS

Top row left, provinces of Ireland; centre, provinces of New Zealand; right, states of U. S. eastern sea-board. Bottom row left, provinces of the South African Union; right, states of eastern Australia.

In Fig. 17 I have shown a number of cases where a single race, or ethnologically similar stock, is spread over a considerable area. In all these instances it appears that higher latitudes are linked with a greater proportion of females in the population.

Where populations have migrated from a warmer to a colder climate, or vice-versa, there may also be a corresponding alteration in the sex ratio. An instance of this

is the increasing ratio of males among the white population of South Africa as one goes northward from the point of first settlement at the Cape. These ratios have been shown in Fig. 17 and should be compared with those for the colored races shown in panels on the figure. It is significant to note that the gradient of the sex-ratios is in the same direction for both populations, although it is likely that they have progressively settled into the Union from separate ends. In the United States also it is interesting to note that there are slightly more females per hundred males (98) for the blacks, whose origin is a hotter climate, than for the whites of native parentage (97) who may be considered as having come from a rather cooler area.

Pitt-Rivers (94), as a result of studying vital statistics for Australian aboriginals, Maoris, and Red Indians, has concluded that an increase in masculinity is correlated with a decreasing population. He also considers that the mixing of pure-blood populations results in increase and a drop in masculinity. It is evident that the effect of climate must be distinguished from this conception of Pitt-Rivers, otherwise populations in warm areas would all be dying out and those in the cooler areas increasing. Actually, it appears that one explanation of the increased masculinity of populations in warmer areas is that the length of life is reduced and that, as the mortality rate of males is somewhat greater than females, the shortening of the length of life acts differentially in favor of the male.

Finally, while most of the cases of dying races come from warm climates, there is one case of a community of Norsemen who settled in Greenland and who died out to the accompaniment of increasing cold (55). It is certainly interesting, and perhaps significant, to note that, in these particular climatic conditions, of 17 bodies whose sex it was possible to determine and which had been taken from graves in this settlement, 10 were women.

CONCLUSION

The evidence of the successive and more complicated living organisms which we know as the evolution theory does not yet include any case of a new species being actually observed to arise. The enormously greater differentiation of the tropical faunas, however, provides circumstantial evidence that the warmer parts of the earth are the most likely cradle for the origin of species.

The study of the chromosomal mechanism and the breeding experiments of geneticists have shown that the segregation of certain genes and the production of a race that will thereafter remain true, may readily occur. In the section on "Sex" we have already seen a case in which temperature has been held to have affected nuclear division with a resultant alteration in the primary sex ratio. In these circumstances we should not find it difficult to expect special segregations of genes or "mutants" to take place more often in lower latitudes. It should be noted that such a view of the origin of species implies a segregation and differentiation of characters already present in the original stock and is therefore analytic rather than synthetic.

However the differentiation into the large number of species now living may have been brought about, in view of our observations on the distribution of animals on the globe, it seems likely that temperature must have played a great part. During that part of the earth's history during which living organisms have been present, there have been warm and cold periods (glacial and inter-glacial epochs) and it may well be that the great-

est numbers of new species were formed in the warm interglacial epochs.

A more immediate application of the deductions made in this paper applies to the problem of over-fishing. In the North Sea, a smaller yield of food-fish is being made for unit time and gear than was formerly the case, and most fishery scientists are agreed that over-fishing is the cause of this condition. Apart from the gross decline of the yield there has also been a change in the relative importance of the species. While, for instance, cod, haddock, and halibut, all northern fish, have declined steadily (18) in the post-war years, two southern ones have increased in importance. The whole catch has declined because the northern species are still the greatest part of the yield. Now this qualitative change might have been of no significance had it not been recently pointed out by Scherhag (106) that a continuous warming up, is going on is the Northern Hemisphere. In these circumstances it appears impossible to say that the reduced yield per unit of effort in the North Sea is due solely to over-fishing. The possibility that the rising temperature is causing an increase in the specific complexity and a decrease in individual size and total bulk in the way that has been suggested in the previous pages remains to be examined as at least a contributory cause.

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COMPARATIVE HEMATOLOGY AND THE FUNCTIONS OF THE LEUCOCYTES

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INTRODUCTION

DESPITE the large bibliography on the blood of the vertebrates the problem of the functions of the leucocytes has not been solved. A final solution of this problem will likely be found only through a thoroughgoing study of the peculiarities of the blood of lower forms, through building up a whole picture of blood, not merely of that portion of it represented by the vertebrates. There is an amazing variation in the wandering cells and blood cells of the series of animals from sponges to man, and yet certain similar types of cells are found throughout the series. Although there is need for much more work on the blood of the invertebrates, a comparative analysis of the information available, if not conclusive, is at least suggestive as to the primitive functions of blood in animals generally.

Sponges

The sponges have no true blood or blood vessels but the parenchyma or mesenchyme occupying the space between the epidermis and the canal system has a variety of cells some of which are free wandering cells. These have separated from an earlier syncytium (Wilson '35). According to Wilson and Penny ('30) some of them are nucleolate, sluggishly amoeboid cells, which vary in appearance. At one end of the nucleolate series the cells are small (about 5 μ) and free from inclusions; at the other end of the series the cells are larger (10 μ) and have inclusions. The small nucleolate cells without inclusions are similar in appearance to vertebrate large lymphocytes and hemocytoblasts. They are primitive cells that differentiate into other cell types. To these smaller hyaline cells without inclusions but with distinctly nucleolate nuclei link on serially other types of mesenchyme cells. The primitive nucleolate cells may in fact differentiate into any type of cell in the sponge.

Some of the nucleolate cells with inclusions are doubtless to be looked upon as macrophages since Wilson and Penny state that the inclusions in some of the larger ones indicate that they may be phagocytes. Furthermore, Penny ('33) finds that nucleolate cells ingest degenerating cells and Wilson ('35) says that the digestion of degenerating nuclei in the metamorphosing sponge seems to be under the influence of the nucleolate cells. I have observed neutral red staining vacuoles in them.

Other wandering cells in the sponge parenchyma, of some species at least, include "gray cells" and "globoferous cells." The gray cells have a non-nucleolate nucleus and in the cytoplasm are small granules which are gray in the living cells and which stain with methylene blue and with Nile blue sulphate. They appear to be reserve food since they are used up

in regeneration of sponges from dissociated cells. I have observed that the granules are negative to neutral red. The globoferous cells are also non-nucleolate cells. The cytoplasm contains one larger homogeneous inclusion and several smaller ones. I have observed other cells, not reported by Wilson and Penny, in teased living tissue of *Microciona prolifera*. They have small vacuoles containing brownian granules that stain with neutral red.

(Koehring ('30) has produced evidence to show that the neutral red reaction in vacuoles indicates proteolytic enzyme activity. Throughout this paper her thesis is tentatively accepted.)

Sponges have no enteric canal into which food is passed for digestion and for diffusion. There seems to be general agreement among students of sponges that the wandering cells of the sponge parenchyma are the principal participants in the nutrition of the organism. In some sponges the amoebocytes share with the porocytes and the choanocytes the function of capturing and digesting food while in others the function of ingestion and digestion, which is largely intracellular, may be taken over almost entirely by the amoebocytes of the parenchyma. For further details concerning digestion in sponges see Lendenfeld (1890), Minchin (1900), Cotte (1904), Van Trigt (1919).

Coelenterates

The coelenterates have no blood vessels and they do not have so extensive mesenchyme or parenchyma as the sponges, but in many forms the middle layer or mesoglea contains wandering cells. I know of no information relative to the existence among these of primitive cells of totipotent capacities although the ectoderm in some cases, the endoderm in others, proliferates nucleolate cells capable of giving rise to asexual or sexual individuals (Braem '08, Hargitt '16). Some of the wandering cells of the mesoglea are phagocytic and nutritive in function. Digestion is begun in the coelenteron through the action of an extracellular protease, which breaks down proteins to polypeptids but not to amino acids, and is completed in the endoderm and wandering cells by intracellular enzymes (Metschnikoff, 1880, Boschma, '25, Yonge, '31, Smith, '37, *et al.*). Smith states that "Nutriment is carried to different parts of the body, and excretory products to the gastric filaments and pleated membranes by wandering cells which pass through the mesoglea." In his animals fed with fish blood corpuscles, partially digested corpuscles were to be seen in the cells of the gastric filaments and in wandering cells at the bases of the filaments and in the mesoglea. Runnström ('29) also notes the presence of wandering cells that carry food. Some of them are loaded with albuminous granules. I have observed these wandering cells with acidophilic granules in some actinians.

Flatworms

Like the sponges, the flatworms have a parenchyma or mesenchyme which occupies the space between the dermal layer and the viscera. Simple forms like *Planaria* have no blood or lymph vessels but merely intercellular lacunae in the parenchyma; others have definite vascular channels, which represent intercellular lacunae walled off.

In the intercellular lacunae and in the vascular channels of those species in which vessels exist, one finds a variety of free cells. Among these are cells with a little basophil cytoplasm surrounding a vesicular nucleus with one or more nucleoli. Various workers (Prenant, '23, Jordan, '33) find these to be homocyto-

blasts and others (Curtis and Schulze, '34) find them to be totipotent cells. Other free cells, varying somewhat in types in different species, are found in the lacunae and blood vessels. A few species are said to have red cells that contain hemoglobin and there are amoeboid cells with acidophil granules and phagocytic cells containing ingested materials.

Although we have inadequate information relative to the part played by the mesenchyme in digestion in flatworms it seems certain that the phagocytic cells and perhaps the granular cells participate in the nutritive process. An enteron is present in most flatworms, but in simple forms like *Planaria* there is no digestion within the lumen. That the epithelium of the gut phagocytoses the food and digests it intracellularly has been known since Metschnikoff's (1880) observations. Later more detailed work has been done by Westblad ('23), Willier, Hyman and Rifenburgh ('25), Kelly ('31). In such forms as *Convoluta* and *Haplodiscus* belonging to the group of the Acoela, there is no gut lumen but a central nucleated mass of protoplasm, the syncytial hypoblast or "digesting parenchyma," in which remnants of prey are found. In *Proporus* and some other turbellarians the digesting parenchyma consists of separate amoeboid cells (Benham, '01a). According to a commonly accepted interpretation the Acoela are looked upon phylogenetically as being degenerate not primitive forms. If this interpretation is correct the presence of a digesting parenchyma is a derived, degenerate condition. However, there is some basis for looking upon them as primitive flatworms. This thesis is supported in an unpublished paper by M. A. Stirewalt.

Echinoderms

The echinoderms do not have a true vascular system but an extensive system of lacunae and sinuses communicating with the body cavities and the exterior. The fluid in the body cavities and the lacunar system is similar except that the coelom is said to contain more sea water and correspondingly less dissolved albumen.

The cells found in the lacunae are identical with those in the coelomic cavities,—in fact they may wander from one location to the other and throughout all the tissues. The blood cells (coelomic corpuscles) of echinoderms have been described by Geddes (1880), Cuenot (1891), Saint-Hilaire (1898), Kollmann ('08), Théel ('20), Kindred ('21, '24, '26), and others. The structure of the different types of cells varies somewhat in different species, and some types are found in all species while others are of limited distribution.

The following cell types appear to be universally distributed within the phylum:

1) Leucocytes with nucleolate nuclei and petaloid or membranous pseudopodia. Goodrich ('19) first described the true nature of their pseudopodia. They have long been recognized as phagocytes: see Kindred ('24) who cites some of the earlier observations. They take up carmine and trypan blue, give a positive oxidase reaction (Ohuye, '36a, b), and contain small neutral red bodies or vacuoles. These cells are probably the echinoderm equivalent of the mammalian macrophage.

2) Cells with spherules, which may be colorless, red, green, yellow, or brown. The cells with colorless spherules are always present and one or more of the colorless types usually occur. Cuénot (1891) believes that these cells arise from cells of the preceding type through the addition of spherules of protein. Kindred ('26) believes that the various colored globules result from the partial digestion of colorless globules. That the various types of spherules differ somewhat in

nature as well as in color is shown by some of their reactions. For example, I have observed that the red spherules of some species (*Arbacic punctulata*, e.g.) are destroyed by weak HCl or by the acid of acidulated methyl green used for the nuclear staining of fresh cells, a reaction suggesting an albuminous composition of the spherules, and that they blacken with osmic acid, whereas the colorless spherules are more distinctly seen after the weak acid and they are negative to osmic acid. It seems probable that they are to be regarded as food carriers. They are neutral red positive and Ohuye ('36a, b) has reported a positive oxidase reaction for the colorless and for the brown globules. Saint-Hilaire (1898) and later workers find them to exist as migratory cells in the tissues, and especially in the wall of the intestine. Cannan ('27) finds that the red pigment in cells of the coelomic fluid and some other tissues of *Arbacia* function as an oxidation reduction system.

In the echinid *Temnopleurus* there are amoebocytes with fine granules that are positive to Best's carmine test for glycogen (Ohuye, '36b).

The following types of cells are of limited distribution:

3) Vesicular and compartment cells with brownian granules in the vacuoles. They are very similar in structure and reactions to cells that I have described elsewhere for tunicates, and they have been reported by various authors as occurring in annelids also. The granules stain with 1 to 8000 neutral red and with 1 to 40,000 Nile blue sulphate and Ohuye ('36b) reports a positive oxidase reaction.

4) Cells with long flagella called "vibratile cells." A few small neutral red granules are present in the cell bodies. In the absence of a heart in echinoderms, these vibratile cells, in conjunction with "ciliated cups" and "urns" and the ciliated epithelium of the coelom, serve to keep the fluid agitated.

5) Red cells, or hemocytes, containing hemoglobin. Such cells are not found in all echinoderms but occur in those holothurians that have a considerable amount of highly contracile muscle and so require efficient oxygen and carbon dioxide exchange (Kindred, '24).

6) Lymphocytes or stem cells. These have not been generally recognized in previously published lists of echinoderm cells although Kollmann does speak of hyaline leucocytes of stage I. They are small spherical cells of the large lymphocyte or hemocytoblast type. In its simplest form the cell has a large vesicular nucleolate nucleus and a thin shell of cytoplasm devoid of neutral red or Nile blue staining granules. Cells interpreted as transitions show a few stainable granules. In the sand-dollar, *Enchopetalus michelini*, such small spherical cells with vesicular nucleolate nuclei and transition stages as well are easily found in coverslip preparations of fresh coelomic fluid stained with neutral red or Nile blue sulphate. The nucleus is revealed after treatment with osmic acid or acidulated methyl green. In sections also I have found these cells in sinuses of the body wall. In the sand-dollars, *Mellita sexiesperforata* and *M. quinquiesperforata*, in the sea urchins, *Arbacia punctulata*, and in some starfishes and holothurians I have found them less easily and in smaller numbers. In some echinoderms I have not been able to find them at all. Theoretically these cells should be number 1 in the group of universally distributed cells. I assume that such cells are always present in the animal although apparently not always as free cells in the circulating fluids. Perhaps in some species of echinoderms, as in the birds and mammals, the hemocytoblasts do not ordinarily leave their site of origin

in the connective tissues under normal physiological conditions.

The opinion that some of the blood cells of echinoderms have a nutritive function is supported by Cuénot (1891) and Kollmann (1908). Their opinion is based in the main upon the extensive occurrence of granules and spherules of fatty and albuminous nature in the cells. The further evidence of positive neutral red and oxidase reactions is confirmatory. Moreover, Van der Heyde and Oomen ('24) consider that fine particles of food are taken up by wandering phagocytes in asteroidea. Oomen ('26a, b) found free amoebocytes in the lumen of the gut and an abundance of them in the epithelium. He, therefore, considers that they play an important part in the absorption and transport of nutrient materials.

Certain observations on the distribution of enzymes are of significance in this connection. Van der Heyde ('22, '23a) and van der Heyde and Oomen ('24) find that the stomach and gut of echinoderms yield a weak proteolytic enzyme but no amylolytic enzymes. Van der Heyde ('23b) confirms Cohnheim's finding of an amylolytic action of echinoderm coelomic fluid, but he concludes from his experiments that this action is due to the consumption of carbohydrate by "blood" corpuscles and not to an enzyme free in the plasma. Weese ('26) finds protease and amylase in extracts of the digestive tract but no lipase. He expresses the opinion that the weak pepsin-like enzyme is perhaps contained in the tissues rather than secreted into the lumen.

Annelids

There is a variety of cells in the blood and coelomic fluid of annelids. The presence of cells of stem-cell type seems established. They have been recorded in many genera by a number of workers some of whom follow: in acanthodrilids by Benham ('01), in *Ctenodrilus* by Galvagni ('05), in *Arenicola*, *Glycera* and sipunculids by Kollmann ('08), in Lumbricidae by Cameron ('32), in various polychaetes by Romieu ('23), in *Drawidia*, *Terebella*, *Thalassema* and Gephyrea by Ohuye ('34, '37a), in *Pheretima* by Kindred ('29) and Ohuye ('37c). Common features of these cells are hyaline basophil cytoplasm, in some cases said to be scanty but in others more abundant than in vertebrates, and a spherical, oval or bean shaped nucleus. In some cases nucleoli are said to be absent (Kindred, '29); in others present. Nucleoli have been recorded in Lumbricidae by Cameron ('32) and in some gephyrean worms by Ohuye ('37a). Romieu ('23) records the presence of both microlymphocytes and cells comparable to hemocytoblasts.

In certain cases hyaline leucocytes have been said to be phagocytic (Romieu, '23, pp. 245, 248, Ohuye, '34, Kindred, '29), but there is evidence that the phagocytes have differentiated beyond the stem cell type. Kollmann ('08) recognizes in *Arenicola* a "stage II" which he says is characterized by an increase in cytoplasm and highly developed amoeboid and phagocytic powers. Phagocytic cells of *Pheretima indica* show petaloid pseudopodia (Kindred, '29) similar to those of vertebrate macrophages, of phagocytic cells of echinoderms and amoeboid cells of various other forms. Camerons ('32) reports that all types of earthworm coelomic corpuscles (but not chloragogen cells) are phagocytic for such things as india ink and carmine, although the larger nongranular cells are most active; and only the large basophilic type of corpuscle phagocytoses foreign cells such as spermatozoa and red blood corpuscles.

In addition to the above blastic cells and phagocytic cells, the blood of anne-

lids has other types of cells. Some of them contain fine or coarse granules, which may be acidophilic or basophilic; others have larger spherules; still others are compartment or vesicular cells (linocytes) similar to those of ascidians and echinoderms. In some cases the inclusions are reported to blacken with osmic acid, stain with Sudan III, and give a positive Millon test and so they are considered to be composed largely of fats and proteins. Very commonly they stain with neutral red, and in some cases they have been reported to give a positive oxidase reaction (Ohuye, '37a); in other cases the granules are said to be oxidase negative (Cameron, '32). Romieu ('23) finds that the leucocytes of polychaetes produce diastases. With regard to the chloragogen cells Cameron ('32) believes that "the fact that they are usually in the process of disintegration, liberating their characteristic granules of lipoid and protein, points in the direction of a metabolic function rather than protective." Conclusive evidence of the participation of the blood and coelomic cells of annelids in nutrition is lacking but the probability that some of the specialized cells have such a function should be considered.

Some species of annelids (*Glycera*, *Thalassema*, e.g.) have cells with respiratory pigments, and sometimes cells are present that are said to have an excretory function.

Brachiopods

Ohuye ('36b, '37b) reports concerning the blood of three genera of brachiopods (*Coptothyris grayi*, *Terebrataria coreanica*, and *Lingula unguis*). His analysis of the cells that he calls hyaline amoebocytes (5–12 μ in diameter) does not make it clear, but probable, that there are primitive spherical cells with a nucleolate nucleus surrounded by a little clear cytoplasm and also larger phagocytic cells with more cytoplasm and probably without a nucleolus. Two of Ohuye's figures show a considerable amount of cytoplasm around the nucleus of these cells; one shows little. He states that the nucleus shows a nucleolus in the majority of cases. In his figures of the hyaline cells of *Lingula* the smaller cells are the ones that show nucleoli.

Ohuye reports other cells with granules of various sorts. Their reactions with osmic acid indicate the presence of fat in the inclusions. Intracellular enzyme activity is indicated by positive neutral red staining and oxidase reactions of the granules. That these cells are probably involved in the digestive processes of the organism is indicated by their inclusions and reactions. Furthermore, Yonge ('37, p. 89) states that there is probably no secretion and hence no digestion in the gut of *Lingula*.

Molluscs

In the lamellibranchs, the group of the molluscs in which the vascular conditions are perhaps best known, the blood is pumped from the heart through a system of more or less dilated vessels and sinuses with connective tissue walls but without an endothelium. In these vessels there are to be found the following types of cells (Cuenot, 1891, Bruyne, 1895, Kollmann, '08, Takatsuki, '34, and others):

1) Small cells with large nuclei and a little hyaline cytoplasm.
2) Phagocytic cells with more cytoplasm than the preceding.
3) Cells with granules in the cytoplasm.

(Cells with large spherules are found in the connective tissue.)

The suggestion was made by some of the earlier investigators that the cells are involved in nutrition. Other workers seem to have shown conclusively that they have an important rôle in the nutri-

tion of the lamellibranchs. Outwandering phagocytes were recognized in the oyster, anodon and other lamellibranchs as long ago as 1893 by Lankester. I have observed them with ingested diatoms in the lumen of the gut. The excellent work of Yonge ('26, '28, '36) has given us considerable detailed information about these cells. He observed the actual digestion of olive oil emulsion and elasmobranch blood corpuscles by oyster phagocytes. Takatsuki ('34) found that the oyster amoebocytes possess sucroclastic, lipoclastic, and proteoclastic enzymes and that they are capable of absorbing glucose. He reports, furthermore, that amoebocytes play an important part in excretion, disposing of foreign indigestible matter by way of the excretory organ, pericardium, surface of the auricle, rectum, and mantle cavity.

Kollmann ('08, p. 65) reports that the granulations in cells of some Unios are much less numerous at the beginning of spring than at the end of autumn, and concludes that they are reserve nutriment. He states that the granular leucocytes so prominent in the lamellibranchs, are not found in the gastropods. The absence of these granular leucocytes in gastropods may bear some relation to the fact that digestion of proteins is extensive in the lumen of the gut of gastropods whereas it is very limited in the gut of lamellibranchs. Yonge ('37) states that throughout the gastropods there is a tendency for intracellular to be replaced by extracellular digestion, but that in certain genera absorption and all digestion of proteins and fats takes place within cells of digestive diverticula. In these genera there are no wandering phagocytes.

Arthropods

The conditions and homologies in the blood of crustaceans and some other arthropods are not yet clear enough to me to justify me in attempting any analysis or generalizations. For data and references to the literature, the interested reader is referred to Kollmann ('08), Tait and Gunn ('20), and Maluf ('39).

Insects

In a recent valuable review with bibliography Mellanby ('39) points out that the blood cells of insects seem to be homologous to vertebrate leucocytes; none are respiratory in function. The corpuscles give the appearance of many different forms, but Mellanby thinks it possible that there is only one type of corpuscle with a different appearance at different stages in its development. He recognizes immature cells (free undifferentiated mesenchyme cells), basophil phagocytes, and eosinophilic non-phagocytic oenocytes of unknown function. The phagocytes, or perhaps the undifferentiated mesenchyme cells, take some part in producing internal membranes, and the phagocytes are important agents in breaking down obsolescent tissues, especially during the pupal period, which they digest and then set free their constituents to be reconstituted into other tissue. They also serve to protect the insect's body against invasion by foreign organisms, which they may ingest or encapsulate.

Ascidians

In ascidians the blood is pumped out from the tubular heart through main vascular channels into the sinuses and tissue spaces of the body. There is no distinction into blood, lymph, and tissue spaces. In the circulating fluid there are certain fundamental types of cells that are of universal occurrence; other cell types with very special functions are found in some species, not in others. Lymphocytes (or lymphoid hemoblasts), phagocytic cells, and cells with vacuoles

that contain inclusions of nutrient materials are present in all species; cells with carotinoid inclusions, nephrocytes, morula cells, and cells with fibrous inclusions have a limited distribution.

The lymphocytes are small, spherical cells with large, pale, nucleolate nuclei surrounded by a small amount of basophil cytoplasm that contains few or no neutral red granules or vacuoles. These cells are hemocytoblasts and transitions connect them with the more specialized cell types. A number of workers (Brien, '30; Devinney; '34, Berrill, '35) find them to be the cells which give rise to all the organs of new individuals in budding and regeneration.

Macrophages have more abundant cytoplasm surrounding the nuclei, which in older stages have lost the nucleoli. The cytoplasm contains neutral red staining vacuoles in which ingested materials are frequently found.

The cells with nutrient inclusions are of a variety of sorts. They have smaller nuclei than the preceding types of cells, and the cell bodies contain large or small vacuoles with fluid or granular inclusions that stain with neutral red and with various other dyes. The nature of the fluid and the inclusions in the vacuoles giving the neutral red reaction, supported by the fact that a positive oxidase reaction has been reported in some of these cells, gives basis for interpreting the reactions that go on within the vacuoles as being hydrolytic or synthetic (or both) chemical changes. In this connection it is worthy of note that Yonge ('25) and Berrill ('29) find in some species of ascidians that the enzymes of the gut lumen are weak and do not complete the splitting of the proteins of the food into amino acids. Furthermore, Henze ('12) corroborates the earlier observation of Krukenberg that the plasma of ascidians is poor in dissolved albumens. These facts have led me to assume that the incompletely hydrolyzed foods diffuse through the wall of the intestine into the vascular lacunae and are taken up into the vacuoles of the blood cells where chemical changes are continued to the point where the nutrient materials are utilizable by those tissues that have little digestive capacity.

There is some histological evidence to support the above view. In the wall of the gut the blood circulates in broad lacunae and comes into direct contact, to a greater or less extent in different species, with the bases of the epithelial cells. It seems that this arrangement would facilitate the passage of materials from the lumen of the gut into the lacunae and absorption by the blood cells. The blood cells subsequently wander freely through the tissues, and sections show blood cells applied to the fixed tissues (muscles, etc.) as if they were serving as nurse cells to these tissues. In fact, many of them are virtually identical in structure with the nurse cells surrounding eggs, and the inclusions of the two are histologically similar. (For further details and bibliographies concerning the blood of ascidians see George ('39) and Webb ('39).)

Vertebrates

In the vertebrates, red cells, which are present in some invertebrates but absent in most, have become the dominant cells—a dominance correlated with differences in respiratory conditions and requirements. On the other hand leucocytes constitute a relatively small proportion of the cells present in vertebrates whereas they are the dominant cells or the only cells present in the circulating blood and body fluids of invertebrates. Are the leucocytes of vertebrates comparable to those of invertebrates, and with what difference in

physiological conditions may their relatively minor proportion be correlated?

It appears that in the vertebrates, including the mammals, there are free cells as well as fixed cells of embryonic potencies comparable to the blastic cells (lymphocytes and fixed mesenchyme cells) of the invertebrates; there are phagocytic cells of limited developmental potencies; and there are granular leucocytes. In the higher vertebrates lymphocytes, lymphoblasts, and hemocytoblasts are recognized, although neither the lymphoblasts nor the morphologically and probably functionally equivalent hemocytoblasts are normally found in the blood stream. They exist as free cells in the lymphoid tissue and bone marrow, and probably are equivalent to fixed mesenchyme cells of the connective tissues. There is much evidence to indicate that the lymphocytes of the blood and lymph channels have potentialities similar to the lymphoblasts, hemocytoblasts, and fixed mesenchyme cells (see Bloom, '37; and other authors), although students of vertebrate blood are not in agreement upon this point.

The vertebrate monocytes and macrophages appear to be comparable though not necessarily identical in structure and functions to the phagocytic cells of the invertebrates. They assist in disposing of foreign bodies and senile or necrotic tissues of the organism and perform other functions. Lewis ('37) has observed that they have membranous processes similar to those of the phagocytic leucocytes of echinoderms and other groups and that these membranous pseudopodia play an important part in the drinking in of body fluids by the cells. Lewis believes that these cells exercise a digesting, modifying action on the body fluids.

Are the granular leucocytes likewise comparable to those invertebrate granular leucocytes to which I have attributed a primarily nutritive function? Their granules are correspondingly neutral red positive and oxidase positive. Furthermore, leucocytes of the vertebrates have been shown to have the power of digesting substances, and various enzymes have been obtained from them (Opie, '22; Willstätter and Rhodewald, '31; Stern, '32).

The reactions of vertebrate blood cells to nutrient materials is significant also. Clark and Clark ('17) demonstrated that experimentally introduced fatty materials incite active migration of leucocytes from blood vessels into extra-vascular tissue, and Emmel, Weatherford, and Stricher ('26) find that there is a passage of leucocytes into the alveoli and ducts of the mammary gland throughout the period of lactation. The increase in the number of leucocytes in areas of inflammation or around endogenous or exogenous dead material or throughout the whole body in certain pathological conditions in which there is abnormal tissue disintegration might be explained as a response of the cells to an increased abundance of undigested materials. Furthermore, it is common knowledge that large numbers of leucocytes, especially lymphocytes, pass through the epithelium of the gut into its lumen. It is not known what significance there is in this phenomenon, but it seems likely that it is a response of cells to nutrient materials. We have seen that a similar phenomenon has a great deal of functional significance in sponges and oysters and, perhaps, in some other forms in which digestion takes place largely intracellularly in the leucocytes. In the vertebrates in which digestion takes place largely extracellularly in the lumen of the gut it may be a persisting reaction without any great physiological usefulness.

Clinicians have observed a close relationship between disturbances of the gastro-intestinal tract and anemias, and, fur-

thermore, there is experimental evidence to show that nutrient materials have a pronounced effect on the production of various types of blood cells. Settles ('20) finds in kittens that a high fat, high calorie diet produces a general enlargement of the lymphoid tissue of the body. Also at the 1938 meetings of the American Association of Anatomists, Prof. C. M. Jackson reported a very great loss of weight in the thymus and other lymphoid organs of rats kept on an inadequate diet and a rapid seven-fold increase in this tissue when the animals were restored to a full diet. Wiseman, Doan, and Erf ('36) find that foreign proteins injected into the body are important factors affecting the production of both lymphocytes and granular leucocytes. Jordan ('38) obtained interesting results from starving salamanders for some weeks. He finds that the leucocytes are greatly reduced in number; the eosinophils completely disappear; the neutrophiles and basophils lose their granules; the production of granulocytes in the liver ceases. After two weeks of adequate feeding there is complete restoration of normal conditions. It is interesting to note that Kollmann ('08) made comparable observations on crabs many years ago. He reports that in these animals the granules in the blood cells become greatly reduced in number during the molting period, during which time the animals do not feed. These observations seem to show that scarcity of nutrient materials in the body fluids causes an alteration in the structure and a reduction in the number of leucocytes and an atrophy of the lymphopoietic tissue; abundance of nutrient materials causes an increase in the number of granules and granular leucocytes and an hypertrophy of the blood-forming tissue up to a certain level.

Further evidence in support of the hypothesis of a primitive nutritive significance of blood is found in the fact that in both the ontogeny and phylogeny of vertebrates blood formation is intimately associated with the digestive tract. The first blood in the embryo is formed in the mesoderm of the yolk sac adjacent to the food-bearing endoderm. Subsequently blood is formed in the liver, which is of gut tract origin and of nutritive significance, and in the spleen and other hemopoietic regions of the gut tract. It is only in the higher vertebrates that the bone marrow takes over the principal blood-forming function, and even in these forms the wall of the gut remains one of the important areas of leucocyte production throughout life. Furthermore, it seems significant that the anti-pernicious anemia principle influencing erythrocyte production originates in the stomach. In the phylogeny of vertebrate hemopoietic tissue it seems evident that the primitive blood-forming tissue is the mesodermal envelope of the enteron. In the hagfish this tissue is diffusely scattered throughout the length of the gastrointestinal tract, but as we ascend the scale of the vertebrates we find special loci of hemogenesis developed (Jordan, '33).

Despite the evidence that I have cited to support the thesis of a primary relationship of the leucocytes to the processes of digestion and nutrition in animals generally, it seems unlikely that the leucocytes normally play a very important part in these processes in mammals or other vertebrates. In the absence of a digestive tract in sponges, other tissues must do the job of splitting the complex proteins, carbohydrates, and fats of the food into simpler molecules that the tissues of the organism can use to do work and build up their own protoplasm. In the sponges and some of the flatworms it has been seen that the parenchyma, the blood homolog, carries out this function. In the ascidians the digestive tract has be-

come an effective digesting organ, but even here it appears that digestion is not completed in the lumen of the gut and the final phases are probably left for the blood cells. Among the vertebrates the epithelium of the gut tract and of the glands derived from it has developed a very efficient enzyme secreting function and the gut has taken over one of the major primitive functions of blood. Nevertheless, it may be that physiological leucocytosis of digestion and pregnancy should be looked upon as a primitive response of the blood forming tissues to an excess of foreign substances of nutritive value. Under pathological conditions the leucocytes come into function in the digestion of dead and dying tissue. So far as their primitive function is concerned it seems that the granular leucocytes of vertebrates may be looked upon as surviving cells that have been largely out moded in the process of evolution. In a sense then they are vestigial. It may be, however, that the leucocytes have taken over certain special metabolic processes related in nature to their original function. For example, the formation of bile pigments, formerly credited to the liver cells, is now recognized as a function of the reticuloendothelial cells (see Lemberg, '38), and one may hazard the suggestion that the leucocytes play a part in the formation of plasma proteins. There is some support for this suggestion in the hyperproteinemia observed in myeloid leucemia (see Luck, '38).

SUMMARY

The vertebrates and most of the invertebrates have free cells of mesenchymatous origin. In some groups these cells are more or less confined to vascular and lymphatic vessels; in others they wander through the tissue spaces. In all groups that have been satisfactorily investigated certain fundamental types of cells are found:

1) Relatively undifferentiated cells that have the capacity to differentiate into other types of blood cells or wandering cells, and, in some groups and possibly in all, into any type of cell in the body including the genital cells.

2) Phagocytic cells that serve the function of consuming foreign materials and dead or damaged tissue of the animal itself.

3) A greater or smaller number of various types of more specialized granular and vacuolated cells that contain nutritive materials and give evidence of enzyme activity. In many low forms these constitute an important part of the food handling and digesting mechanism. In other forms, including the vertebrates, their original function has been taken over largely by the digestive glands of the gut tract.

Of limited distribution, present in animals of some groups but not in others, are specialized cells of a variety of types serving other special functions characteristic for the animals in which they are found. To be included here are such cells as the cells with respiratory pigments found in the vertebrates and some invertebrates with high oxygen requirements; the carotene bearing cells and the excretory cells of some ascidians; and the flagellate cells of some echinoderms which, in the absence of a heart, keep the fluid in circulation.

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THE LABORATORY POPULATION AS A TEST OF A COMPREHENSIVE ECOLOGICAL SYSTEM (*Concluded*)

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Aggregation and Coaction

EARLIER in this paper the point was made that aggregation occurs in nature, and, as a result, coactions are set up. These coactions are designated in terms of their end-effect on the population as co-operation, disoperation, and competition. It is our plan to illustrate these three forms of coaction by the data of experimental population studies. One clarification is necessary before proceeding. We shall be discussing *Tribolium* and *Drosophila*. Populations of these species are aggregations in the statistical sense that they are groups of organisms, and in the biological sense that they respond as a unit or population integrated by biological processes. They are not, however, as closely-knit aggregations as can be studied under laboratory conditions. Laboratory aggregations often occur without physical crowding within a habitat. This means that their reality as aggregations does not depend on spatial confinement. A few examples of the latter follow: aggregations of *Paramecium*, terrestrial isopods, schooling fish, all truly social insects, *Asellus* (isopod) and certain amphipods during the breeding season, many birds under night roosting conditions, earthworms when the soil loses moisture, tubifex worms, mice at night or when the temperature lowers, and so on. These aggregations also furnish interesting material for coaction analyses. They can not be studied here but the writings of Allee (1931; 1934; 1938) should be consulted for further information.

Co-operation

Tribolium. Chapman (1928) in his stimulating paper on biotic potential incidentally published some data that furnished the impetus for a study of co-operative coaction during the early growth of *Tribolium* populations. These data are reproduced in Table 6. There reproductive performance in beetle cultures started at different population densities is summarized. Among other things, the table shows that at the first two censuses, 11 and 25 days, a population of intermediate size (two pairs of beetles in 32 grams of flour or 0.125 beetles per gram) produced more progeny per female than smaller or larger cultures. The significance of this point was neglected by Chapman but stressed by Allee (1931, p. 179) as another possible illustration of "undercrowding." An undercrowding effect exists when, for any biological process, the maximum response consistently occurs, not in the population of least possible density, but in a somewhat more crowded culture. When such an effect is shown, either for

natural or laboratory populations, to be due primarily to coaction then co-operation in the sense of Clements and Shelford has been demonstrated. By focusing attention on Chapman's protocol Allee stimulated MacLagan (1932) and Park (1932, 1933) to test this phenomenon independently. These two studies showed that the effect suggested in Chapman's original paper could be reduplicated. In other words, two pairs of *Tribolium* in 32 grams of flour produced significantly more eggs per female at the time of the first egg census than did smaller (1 pair) or larger (4, 8, 16, 32 pairs) populations.

With the reality of the effect established, an analysis of causal factors was undertaken. Here, MacLagan and Park reached different conclusions. The former suggested that at the optimal density a "sensitisation" (p. 443) of the organisms took place; probably through some psychological mechanism. In a later paper MacLagan and Dunn (1936) worked with a weevil, *Sitophilus oryzae*, and concluded that, ". . . living organisms are not always the highly coördinated physiological units they are often represented to be . . . and some should be regarded as heterogeneous assemblages of diverse physiological processes, each with its own optimum, rather than harmonious physiological units" (p. 136).

Park (1933, p. 40) suggested a different type of explanation for the observed optimum density effect. He said,

> "This [effect] was found to be due to the interaction of two factors. The first factor was egg eating, or cannibalism. This reduced population growth rate in more crowded cultures since more eggs would be found by random moving beetles and eaten. The factor then favors greatest increase in minimal sized groups. The second factor was the question of frequency of copulations. It was found that recopulation was stimulating to reproductive productivity and since more copulations were occurring in concentrated populations this fact favored greatest increase in maximal sized groups. The interaction of these factors, one favoring maximal growth in small populations and the other favoring maximal growth in large populations, would cause an intermediate sized population to have greatest initial increase."

Let us examine this initial population effect as an illustration of Clements' and Shelford's co-operative coaction. Two questions immediately arise: (1) to what extent is this effect really co-operation, and (2) what are the major coactions involved? Turning to the first question it appears that the effect is co-operative, i.e. of benefit to the population, from a short-time viewpoint only. It has been shown that certain *Tribolium* populations of intermediate density have a higher productivity *per adult beetle* during their early history than larger or smaller cultures. This may be of some value in aiding these populations to get established and from this point of view the effect can be called co-operative. However, Chapman (1928) showed that all *Tribolium* cultures eventually reached a similar numerical equilibrium in terms of beetles per gram of medium (43.97 ± 2.88 for his culture conditions) that was independent of the initial density conditions. This means that the early optimal effect may be

TABLE 6

Data of Chapman (1928) recalculated to emphasize the initial optimal population effect

Volume of medium (gm.)	32	32	32	32	32	32
Imagoes (pairs)	1	2	4	8	16	32
Beetles per gram	0.026	0.125	0.25	0.5	1.0	2.0
Progeny per imago per day	1.59	3.90	3.18	2.82	2.36	1.82

of no permanent importance in the total population life-history.

The effect is worthy of analysis, however, because (1) it illustrates in the laboratory a type of response that is frequently of real significance in the establishment of field communities, and (2) it focuses attention on a series of coactions that are important in the integration of *Tribolium* populations. The analysis of Park summarized above shows that the optimal population effect results more from the secondary or coaction cycle than from the primary or action-reaction cycle. The important coactions are egg-eating and copulation frequency. Egg eating occurs in direct proportion to imago density and egg density. When taken by itself, this co-action is really a good example of competition since the beetles compete for a limited supply of eggs. However, in conjunction with copulation it results in the co-operative end-effect noted. The copulation coaction is based on the beetles' sexual behavior; namely, random movement with copulations a frequent result of the meeting of males and females. Thus, up to a point, copulation frequency is also in direct ratio to imago density. The population significance of this coaction lies in its stimulatory effect, again within limits, upon the fecundity of female *Tribolium*. We must recognize that the importance of these copulation and recopulation effects is not limited to the initial populations; this is a coaction that is probably essential in all *Tribolium* cultures.

Before passing on to *Drosophila* another brief example of co-operation in *Tribolium* populations should be noted. The beetles (imagoes and larvae) are continually moving through their flour. In certain kinds of flour this movement is difficult for newly established cultures because there are no tunnels. The early members of a culture prepare the medium through their own activity for the use of forms to come by creating such passageways. This statement should not be construed as teleological. While the significance of this effect has not been investigated, it seems safe to guess that it is of enough influence to warrant notice. It will be recalled that this effect was mentioned under reaction. It was properly introduced there and properly included here. The reaction is, obviously, the alteration imposed on the habitat. The coaction is based on the fact that all the beetles move, and move with reference to each other through the flour.

Drosophila. One of the most striking laboratory demonstrations of co-operation has been reported by Pearl, Miner and Parker (1927) in their studies on the effect of imago population density on the duration of adult life in *Drosophila*. As we shall see the conclusions reached in this investigation are clear although the causal factors unfortunately have not been analyzed. The experiments are particularly important in the population sense because they deal with mortality. The basic data are presented in abbreviated form in Table 7 and are well summarized by Hammond (1939) who says,

"... the flies, just a few hours old, were placed in one-ounce glass vials with banana-agar medium seeded with a standard amount of yeast. The vials were closed with cotton plugs permitting circulation of air. Each day the flies were changed to a new vial and any dead flies counted (but not replaced.) Two, 4, 6, 8, ... 125, 150 and 200 flies (20 steps in all) were initially placed in each vial, there being a total of 530 vials and 13,000 flies in all. As was to be expected, the higher densities considerably shortened the duration of life but the more significant point was that up to a density of between 30 and 55 flies per vial at the start *increasing density significantly prolonged the duration of life*. ... Further studies showed that densities above 200 flies per bottle at the start had little further effect in reducing the duration of life. In other experiments, flies were started in

high and in low densities and then changed to the opposite condition after the sixteenth day of life. It was found that crowding has the most marked effect on mortality in early life. Flies which survived densely crowded conditions in early life were nevertheless weakened so that when they were transferred to an uncrowded environment they did not live as long as they would have, had they never been crowded" (p. 39–40).

TABLE 7

Life-duration of Drosophila at different population densities

(Data of Pearl, Miner and Parker, 1927.)

INITIAL DENSITY (*Imagos per bottle*)	MEAN DURATION OF LIFE (*days*)
2	27.31 ±0.58
4	29.32 ±0.60
6	34.45 ±0.65
8	34.20 ±0.61
10	36.22 ±0.72
12	34.31 ±0.61
15	37.92 ±0.66
20	37.07 ±0.55
25	37.47 ±0.49
35	39.43 ±0.67
45	37.46 ±0.51
55	40.04 ±0.53
65	35.25 ±0.45
75	32.34 ±0.46
85	30.10 ±0.36
95	27.17 ±0.36
105	24.20 ±0.32
125	19.60 ±0.28
150	16.17 ±0.24
200	11.93 ±0.20

This intermediate density optimum for longevity has also been reported independently by Bodenheimer (1938) working with his Palestine strain of *Drosophila* and using different techniques. His data are summarized in Table 8. Bodenheimer says, "Pearl's classical results are therewith fully confirmed: longevity shows a clear-cut density optimum, and is shorter when population density is lower or higher" (p. 56).

There seems to be no reasonable doubt that both undercrowding and overcrowding shorten the life-span of *Drosophila*. In other words, a co-operative response is induced by optimal density. What the coactions, as well as possible action-reactions, are that have such an important influence on adult *Drosophila* is not known. Allee (1931, p. 245) has suggested,

". . . the reduction in length of life at sub-optimal densities may be an expression of the inability of the small populations present to gain control of "wild" organisms other than the food yeasts present in the culture, while the supra-optimal density effects may be related at least in part to food shortage and to excess of excretion products . . . we have here one of the most suggestive of the phenomena yet presented."

TABLE 8

Life-duration of Palestine Drosophila at different population densities

(Data of Bodenheimer, 1938.)

Initial imago density (pairs)	2	4	8	16	32	64
Mean life-duration (days)	12.0	28.5	37.0	37.4	37.4	16.0

This, of course, is partly conjecture. The analysis of the causal factors involved in the whole question is a problem worthy of warm welcome.

There is another aspect of *Drosophila* mortality that should be mentioned here for the sake of the record although there is little experimental information about it at present. This concerns pre-imaginal or metamorphic mortality as influenced by density. We have seen and will see further the importance of this in *Tribolium* populations. For *Drosophila* there is only the suggestion of Winsor (1937) who says,

". . . the data on fecundity and fertility relative to density of population in *Drosophila* indicate a pre-

imaginal mortality varying markedly with density. This mortality may reach 90 to 99 per cent at high densities such as correspond to saturation levels of population. It seems highly probable that this mortality is a factor of major importance in the regulation of numbers" (p. 351).

This is another first-rate problem requiring the attention of the population student.

The suggestion that there is a relation between fly and yeast populations may illustrate in itself a significant co-operative coaction. Hammond (1939, p. 35) recognizes this point when he says, "A loose symbiosis exists between yeast and *Drosophila*, the yeast being spread by the flies which depend upon it to synthesize many non-protein compounds into proteins for themselves." There is a close corollary of this problem in that the flies may control to some extent the growth of mold as well as of yeast. If this is true it is another example of co-operation. Here then are two possible coactions awaiting quantitative analysis. Eigenbrodt (1925) has presented some data that are pertinent. This paper is summarized by Allee (1931, p. 148) as follows:

"The observations of Eigenbrodt that *Drosophila* grow larger in small culture vials when present in numbers of from 8 to 16 than at other population densities may be explained on the assumption that too few *Drosophila* larvae per culture fail to control the growth of harmful elements of the yeast or bacterial flora as well as optimal numbers do, while overcrowding overcontrols the growth of the food plant. This would result in a growth optimum occurring, as suggested, at a relatively low population density but distinctly above the minimum populations studied."

The two outstanding cases of co-operation for *Drosophila* have been presented: population optimum for longevity and fly-yeast (or mold) ratio. In the section on competition we shall discuss density of population in relation to egg production and show that the latter response is adversely affected by crowding. However, before leaving this section a possible co-operation effect analogous to the initial optimal situation in *Tribolium* can be suggested. It must be stressed that this effect is not put forward as knowledge but merely as a possibility and stimulus for further research. In his 1932 paper, Pearl published a table (his Table 5) showing clearly that fecundity in *Drosophila* fell off with population density. There was one discrepancy in these data. The table shows the following oviposition rates for the quarter-pint bottle cultures in terms of "eggs per 1000 female hours' exposure":

Initial density (pairs per bottle)	*Eggs*
1	733.0
2	839.0
4	658.5
8	567.5

It is apparent at once that the two-pair population *for this case* has a much higher fecundity performance than the 1, 4, or 8 populations. This may be merely a chance deviation; however, it is enough like the original suggestion in Chapman's paper on *Tribolium* to warrant further analysis. Murroughs (1940) presents some preliminary data that suggest such an effect may be a real one for *Drosophila* populations but his results are not yet conclusive.

Disoperation

Tribolium. Earlier, we discussed the conditioned flour problem as an aspect of reaction. It was pointed out that conditioning is a modification imposed on the habitat by the population. It was also stressed that this modification is deleterious in its action. It causes population decline by adversely affecting reproduction and post-embryonic development. The position was adopted that it is difficult to

differentiate between conditioning as reaction and conditioning as disoperation. This differentiation can be accomplished on hypothetical grounds by assuming that, of the total conditioned flour produced by a particular culture, one increment depends on the summed influence of *individual* beetles on their habitat while the other increment depends on the summed influence of *inter-individual* beetle behavior (coaction) on the same habitat. Obviously, these two increments are not equal fractions of the whole necessarily. Although this is an entertaining theoretical distinction it is not too valuable in a pragmatic analysis of *Tribolium* population dynamics. However, there is one phase of conditioning that may be discussed more under the category of disoperation than reaction. This is the *rate* at which a culture manufactures conditioned flour. It can be shown for a constant time interval that conditioning varies in direct ratio to density. It is true that this rate phase is due to reaction but it is due more perhaps to disoperation since the disoperative coactions compound as population density increases. When flour is conditioned such effects as reduction of nutritive level and increased contamination occur. These are reactions. As *Tribolium* populations get more crowded, however, contacts between beetles and competition pressures increase. These are coactions. Obviously, not all these coactions are concerned with conditioning but some undoubtedly are.

A recent study (Park, 1938) can serve as an illustration of this rate effect. Experiments were designed to analyze the relation of habitat conditioning to the "efficiency" of *Tribolium* metamorphosis. Efficiency was measured by studying as groups the duration and mortality of the larval and pupal period. In setting up the experiments a series of populations, ranging in density from one to 256 larvae per bottle, were established. All beetles were started in four grams of fresh (i.e. unconditioned) flour. Each bottle was examined at 48 hour intervals and deaths were recorded. The flour was not replaced at any time during the experiment. The results are quite clear-cut. Tables 9 and 10 show that, as larval crowding gets more severe, rate of larval development strikingly decreases and larval and pupal mortality increase. The data may be interpreted in this fashion. In the experiments the flour becomes cumulatively more conditioned with age and crowding. The higher densities condition their habitat at a much faster rate than the lower densities as evidenced by performance during metamorphosis. This conditioned flour acts back on the developing population causing the results noted. It was

TABLE 9

Larval and pupal mortality of Tribolium relative to different larval densities

(Data of Park, 1938.)

DENSITY (*larvae per gram flour*)	LARVAL MORTALITY (*per cent*)	PUPAL MORTALITY (*per cent*)
0.25	9.4	1.6
1.0	7.8	6.2
4.0	39.1	26.6
8.0	75.0	46.9
16.0	108.6	56.2

TABLE 10

Duration of the Tribolium larval period relative to different larval densities

(Data of Park, 1938.)

DENSITY (*larvae per gram flour*)	MEAN LENGTH OF LARVAL PERIOD (*days*)	STANDARD DEVIATION (*days*)
0.25	38.3 ±0.41	4.9 ±0.28
1.0	38.7 ±0.41	4.9 ±0.28
4.0	52.0 ±0.95	11.3 ±0.67
8.0	92.1 ±2.53	30.1 ±1.78
16.0	141.4 ±2.22	37.8 ±1.58

proved that the density effect was due to conditioning rather than to inter-beetle competition (coaction) for, when the flour was kept from getting conditioned by changing to fresh flour every 48 hours, the crowded larvae passed through their metamorphosis about as efficiently as the isolated larvae. A later investigation (Park, Miller and Lutherman, 1939) has shown that the same effects on larval and pupal mortality can be obtained if the flour is conditioned by imagoes instead of by larvae.

This study on metamorphosis suggests that the habitat is conditioned both by reaction and disoperation with every beetle thus participating in the primary and secondary cycles of cause and effect. The study was introduced under disoperation rather than reaction to suggest that disoperations may be more influential in controlling the rate of conditioning than reactions. It will be apparent to the critical reader, however, that this is essentially an arbitrary and perhaps unimportant position. In short, on the basis of knowledge to date it is impracticable to differentiate between reaction and disoperation when applied to the *Tribolium* conditioning problem. This is not necessarily a criticism of the ecological concepts themselves; it is an admission of our inability to distinguish them, with any cogency, in this instance.

An interesting case of disoperation can be constructed from a report of Chapman's (1926). This writer observed that if *Tribolium* imagoes were stimulated by rubbing they released a gas into the habitat "... which smells not unlike an aldehyde. It irritates the mucus membranes of the nose and turns flour and certain other materials pink, and in high concentrations, affects the eyes" (p. 295). It was shown that when larvae were exposed to this gas about 10 per cent of them underwent abnormal development.

"The monsters produced by altering the larval transformation are usually winged larvae. . . . A series of forms has been produced in which one can follow the development of the wing pads from the smallest projections from the sides of the thorax to full-sized pupal wing pads. . . . The larvae which have responded in this way have been those which were in the last larval instar at the time they were exposed to gas. Consequently, the molt which produced the winged larvae was the one which would normally produce the pupae" (p. 296).

These abnormal larvae did not pass through their pupal period. Chapman showed that if the pupae were subjected to the gas they would emerge as teratologic imagoes. Similar cases, known as prothetely and metathetely and due to other causes, have been reported for *Tribolium confusum* by various writers (see Nagel, 1934; Oosthuizen and Shepard, 1936; Wigglesworth, 1939).

I have noted this gas many times in *Tribolium* cultures and have also seen abnormal larvae. In all such cases the imagoes were crowded intensely and their movement was increased markedly by the presence of their fellows. This is clear-cut disoperation since (1) the imagoes are stimulated by the behavior of their neighbors (coaction); (2) as a result of this coaction the gas is liberated; (3) the gas modifies the habitat—both flour and atmosphere; and (4) this modification has a deleterious influence on larval development. Obviously, this is not an important coaction in *Tribolium* cultures because of its infrequency. But it is an excellent illustration of disoperation in the Clements-Shelford sense and as such merits our interest.

Recently, Stanley (1938) has reported some data for *Tribolium* that are instructive examples of disoperation. His experiments are well summarized in his own words as follows:

"Experiments are described in which adults of *Tribolium confusum* Duv. are maintained at 27°C., and 75 per cent relative humidity in four different media: (a) ordinary whole wheat flour sifted through 76-mesh bolting cloth, (b) similar flour with from 30 to 135 *Tribolium* eggs per gram, (c) sifted whole wheat flour plus 3 per cent of finely ground wheat germ and (d) Flour plus germ plus eggs. It is shown that when large numbers of eggs are eaten, there is a serious decline in egg production unless wheat germ in excess is also present. This is believed to be due to a scarcity of certain accessory growth substances found in wheat germ but not to the same extent in eggs" (p. 300).

In this case the *Tribolium* add eggs to their habitat as they would any other metabolic by-product. This is a coaction response because oviposition depends on copulation contacts. The eggs are eaten indiscriminately along with flour. If eaten excessively, without supplementary wheat germ, the cannibalism results in disoperation by reducing the fecundity of female beetles. The possible stimulating effect of eggs plus flour plus germ if real should prove to be an illustration of co-operation. This is suggested by Stanley's statement (p. 300), "When ground wheat germ is present, the beetles seem to do somewhat better in the presence of eggs, possibly because of a better water supply, obtained from the eggs." This is an enticing suggestion awaiting further empirical analysis.

Drosophila. Unfortunately, I am unable to find any good illustration of disoperation for *Drosophila* populations. Obviously, this does not mean that this coaction system is not working within these cultures; it means either that I have overlooked a case already in print or else there is no such report as yet. The "intoxication" effect suggested by Bodenheimer was dealt with under reaction. Possibly it belongs here too but the data are so meagre that nothing more can be said at the moment.

Competition

As discussed earlier we shall view competition as a population pressure resulting from the demand made by many organisms on a limited supply of raw material. This demand does not lead necessarily to a specific end-effect in terms of total population success although it is deleterious usually from a short-time viewpoint.

Tribolium. An interesting case of competition occurring among *Tribolium* populations is cannibalism. This phenomenon was first noted by Chapman (1928) and has been analyzed further by Stanley (1932), Park (1932, 1933, 1934a), and Chapman and Baird (1934). We have discussed it under co-operation as a process working in conjunction with copulation frequency to bring about an initial optimal density effect. Here, we are interested in it as a competitive coaction. In a sense, cannibalism is a predator-prey relationship with larvae and imagoes the predators and eggs and pupae the prey. The possible competition coactions are as follows: (1) larvae with larvae; (2) larvae with imagoes; and (3) imagoes with imagoes. In all cases the prey is limited. However, the density of eggs and pupae, as well as the density of larvae and imagoes, controls the intensity of competition. When the predators are numerous and the prey sparse competition is severe; when the predators are few and the prey numerous competition is moderate.

It has been shown in the laboratory (Park, 1933) that (1) imagoes follow a random pattern of movement through their medium and may eat eggs as they come upon them, and (2) males, virgin females, and fecundated females eat eggs at a statistically equivalent rate. The latter point is supported by the data of Table 11. In Table 12 egg eating rates are given for male beetles maintained at

different population densities. These data corroborate the point made above that cannibalism varies directly with predator concentration.

What is the importance of cannibalism in terms of the total population? This question has been analyzed partially by Chapman (1928) who showed that under controlled habitat conditions *Tribolium* populations eventually reach an equilibrium point in terms of beetles per gram of flour that is constant regardless of the initial density conditions. He explained this equilibrium somewhat as follows. In young, growing populations the imagoes and larvae are not numerous as they are in older cultures so that the eggs have a better chance of hatching into larval forms. As the population approaches its asymptote more eggs are being produced, since more females are present; but, also, more eggs are being eaten. The actual equilibrium, according to Chapman, represents a condition where the relation between number of eggs laid and number consumed is fairly constant and is a situation, of course, in which the maximum *effective* reproduction occurs. In a later paper, Chapman and Whang (1934) analyzed further some of these relationships and showed that during early population growth the eggs, larvae, and pupae undergo fluctuations in numbers due, at least in part, to cannibalistic pressure. While I think the equilibrium mechanism pointed out by Chapman is highly over-simplified, nevertheless, it does furnish an excellent illustration of the rôle played by an important competition pressure in shaping population growth.

TABLE 11

Egg-eating rates of imago Tribolium

(Data of Park, 1933.)

PREDATOR	NUMBER TESTED	MEAN NUMBER EGGS EATEN PER BEETLE PER 11 DAYS
Males	40	7.1
Virgin females	40	7.3
Fecundated females	40	6.5

TABLE 12

Egg-eating relative to imago density

(Data of Chapman and Baird, 1934.)

MALE DENSITY (*imagoes per gram*)	PERCENTAGE REDUCTION OF A CONSTANT NUMBER OF EGGS OVER 7 DAYS
0.5	10.3
1.0	11.0
2.0	13.2
4.0	13.8
8.0	25.9
16.0	40.0

We can summarize this case of cannibalism as an example of competitive coaction as follows: (1) imago and larval *Tribolium* move at random through the flour; (2) eggs and pupae, as well as imagoes and larvae, are distributed randomly through the flour in varying but always *limited* numbers; (3) the former may eat the eggs, and to a lesser extent the pupae, as they encounter them; this is the behavioristic basis for the coaction; (4) the coaction or competition is the aggregate cannibalistic pressure as it occurs in the entire culture; (5) this competition varies with the numerical density of predator and prey and has definite end-effects on the population life-history; and (6) the competition is for food primarily and possibly for water secondarily.

The case of *Tribolium* cannibalism is an example of intra-specific competition. Competition can also be viewed from an inter-specific aspect. There are a number of excellent illustrations to be found in the literature dealing with micro-organisms;

for example, populations of *Paramecium* and *Didinium*, *Paramecium* and yeast, etc. These are well reviewed by Gause (1934) and fall somewhat outside the scope of a paper devoted to insects. Suffice it to say that most of these coactions are competitions for space and food.

A recent paper (Park, Gregg and Lutherman, 1941) reports studies dealing with inter-specific competition between three species of grain beetles: *Tribolium confusum*, *Gnathoceros cornutus* (both tenebrionids), and *Trogoderma versicolor* (a dermestid). This investigation is not yet complete so that a full summary is impossible at the moment. However, certain relevant points can be made. The quantitative results are essentially clear; the coactions involved are not yet analyzed. In these experiments a medium was developed that (1) proved suitable for all three species, and (2) could be sifted for census taking. The total habitat was kept as optimal as possible by replacing the medium at each examination period; by using the same volume of flour in all populations, and by maintaining temperature, relative humidity, and light at certain constant points. At regular intervals counts of larval, pupal, and imaginal beetles were taken. The populations were set up as follows: Control A, consisting of one species only; Control B, consisting of two species introduced in initially equal densities; and Experiment C, consisting of various species' combinations with one form introduced at a numerical advantage over the other. These experiments have been under way for over 700 days with regular examinations at 30 day intervals. The following tentative conclusions can be advanced: (1) as single species populations *Tribolium*, *Gnathoceros*, and *Trogoderma* give evidence of some cyclic fluctuation or oscillation in numbers with age; (2) in mixed populations *Trogoderma* and *Gnathoceros* typically are driven out by *Tribolium*, irrespective of initial densities although under certain conditions *Gnathoceros* drives out *Tribolium*, and (3) in mixed populations *Trogoderma* and *Gnathoceros* are more closely matched although *Gnathoceros* appears to be favored somewhat. Obviously there is fodder here for a long discussion. Our point may be made by focusing attention on conclusion 2 above. Here is a case where one species eventually drives out another. In this instance habitat modifications (action, disoperation, and reaction) are minimized by maintaining experimentally the habitat as optimal as it is possible to do so. Even so, one population controls another and eventually supplants it. To a large measure this control must result from coactions between both competing species. These species are exploiting some common, but limited, material or source of energy. The naming and delineation of the particular coactions involved in this case must await further experimentation. We do have here, however, an example of inter-specific population pressure where the control is apparently due to competition.

Drosophila. As an example of competition in fruit-fly populations the effect of population density on fecundity may be discussed. In 1922, Pearl and Parker set up initial populations of flies at concentrations ranging from one pair per half-pint bottle to 50 pairs per half-pint bottle and counted the number of progeny produced by the different densities. They were able to show that as the population density increased the number of offspring per bottle decreased. In other words, productivity stood in inverse ratio to population density. The authors made no attempt to explain this descriptive result at the time, simply pointing out

that the phenomenon was one characteristic of many types of populations.

In a later paper, Pearl (1932) designed experiments to answer these questions: (1) what physiological process or processes which would explain the type of result just summarized is influenced by density, and (2) what factor or factors, dependent upon density, influence this process? In considering the first point it was reasoned that in short-lived populations where mortality was not important the rate of reproduction must be the factor varying between the different densities. That is to say, the flies would have to reproduce faster at low densities than at high to explain the observed results. This differential in reproduction could be due to an alteration of fecundity, of fertility, or both. Experiments were started in which the initial densities varied in geometric series from one to 128 pairs of *Drosophila* per bottle. The eggs were collected at regular intervals from each container and counted. It was shown that the fecundity was greatly influenced by the number of imago flies in the bottle, since the oviposition, expressed as a rate per female per day, fell off rapidly as the density increased. No important relations between fertility and density were reported; this remains an excellent problem for experimental attack.

From this particular analysis two facts emerge: (1) the description of a specific relationship between population density and population growth, and (2) the demonstration that this relationship is due, in part at least, to a differential alteration of fecundity performance. An analysis of the factors actually influencing the fecundity logically follows as the next step. To answer this question Pearl set up experiments in which the air volume in the bottles above the medium was varied but the area of agar surface was kept constant. The results are summarized in Table 13. It was found that, while the extent of the air space above the culture medium had no significant effect on oviposition, the extent of crowding of the flies on the agar surface was highly important in altering their fecundity. To put differently, the real density effect occurs when the flies are crowded together on this surface.

TABLE 13

Oviposition of Drosophila on a constant agar surface area under varying conditions of density and air volume

(Data of Pearl, 1932.)

INITIAL DENSITY (*pairs per bottle*)	EGGS PER 1000 FEMALE HOURS' EXPOSURE	
	Half-pint bottles	Quarter-pint bottles
1	869.8	733.0
2	606.2	839.7
4	529.0	658.5
8	557.1	567.5
16	340.6	338.0
32	176.6	186.7
64	104.4	129.4
128	108.5	120.8
Mean	178.5	201.7

Bodenheimer (1938) reports experiments that substantiate the conclusion just advanced; namely, that agar *area* is the important factor in shaping *Drosophila* productivity. He set up three series of experiments in which the relation of (a) volume of agar and (b) volume of air space to total population size was assayed. In all series the exposed agar surface was the same. The data are tabulated in Table 14 from which it is apparent that all the populations reach a similar asymptote irrespective of the two experimental variables.

Thus the possible action, reaction, and

coaction processes which control population fecundity have their major origin in agar surface relationships. As in the *Tribolium*, *Gnathoceros*, *Trogoderma* case earlier discussed, the rôle of the primary cycle and disoperation is somewhat minimized in Pearl's experiments since he supplied the flies with fresh agar daily. This suggests that coaction is involved. This coaction must be competition and not co-operation because the effect of increasing density is injurious in terms of culture growth. Pearl made elaborate observations on the behavior of imago *Drosophila* under conditions of minimal and maximal crowding. He reached the conclusions that (1) the flies will not oviposit if they are in contact with, or disturbed by, other flies; (2) crowded flies stimulate each other so excessively that energy is dissipated that might otherwise be used in reproduction; and (3) individual imagoes do not obtain their full share of food (from the agar surface) under these crowded conditions due to the disturbance of their feeding behavior brought about by their neighbors. The latter point holds true even though there is more than enough food present for the total imaginal population. Plainly, these are competitive coactions. As cultures get more crowded flies compete with each other primarily for food and oviposition niches. This competition results in a lowered fecundity. Since the coactions compound with density, fecundity drops off rapidly as the flies get more crowded. Finally, this reaches a place, above 100 flies per bottle, where egg production is not affected further to any appreciable extent.

TABLE 14

Further data on volume and area relationships in Drosophila fecundity

(Data of Bodenheimer, 1938.)

EXPERIMENTAL VARIABLES	SERIES		
	1	2	3
Agar surface (diameter cm.)	5·5	5·5	5·5
Agar volume (c.c.)	26.4	26.4	52.8
Air volume (c.c.)	149.6	74.8	74.8
Asymptotic population (maximum no. flies)	206.	205.	205.

Inter-specific competition in fly populations

A recent paper by Vladimerova and Smirnov (1938) reports some interesting data on competition, and to a lesser extent co-operation, in populations of *Musca domestica* and *Phormia groenlandica*. In this study both single species and mixed species larval cultures were set up. The data are well summarized by Trager (1940) in *Biological Abstracts* (May) in the following words:

"Larvae of both species of flies were placed, two hours or less after hatching, in counted numbers on weighed pieces of beef liver. By increasing the number of larvae, the amount of food available per larva was decreased. The cultures were kept at 25°C., and were allowed to pupate in sand. The number and weight of pupae obtained were determined. In homogeneous populations of each species the mean pupal weight decreased with increasing number of larvae per gram of food, rapidly at first and then more slowly to a minimal value. The total mass of pupae produced increased at first, almost in direct proportion to increase in the number of larvae until it reached a maximum and fell off with further increase in numbers. At the same time, the percentage of survival also decreased. In mixed populations, the relation between mean pupal weight and population density remained the same. However, for *Musca*, the total mass of pupae continued to increase farther with increasing original population and reached a higher maximum than in pure populations, while the reverse was true for *Phormia*. Larvae of the latter are apparently more sensitive to crowding and die off sooner."

From our viewpoint this study is significant in three ways: (1) it provides a new illustration of inter-specific population pressure using new laboratory animals; (2) it implements further the notion that, as population density in-

creases, certain coactions result in intensified competition for food followed by noticeable retardation of growth; and (3) it suggests a new instance of co-operation linked intimately with competition within a single microcosm. The last point emerges from the investigation since it is shown that, in the mixed populations, *Musca* produce a greater total mass of pupae than they do in single species cultures. In short, there is something stimulating *for the housefly* (*Musca*) that grows out of its association with *Phormia*. On the other hand, the latter species has its pupal production retarded by association with *Musca*. This is probably a case of competition primarily (e.g. for food) although more evidence is needed before a definite conclusion can be reached. There are some pregnant problems awaiting attack here. Along these lines a paper by Omori (1939) on the "cohabitation" and cross-mating of two species of *Cimex* (*C. lectularius* and *C. hemipterus*) should be examined also.

DISCUSSION

We have now covered in some detail certain of the major ecological concepts developed by Clements and Shelford and have illustrated these concepts with examples taken from the literature dealing with *Tribolium* and *Drosophila*. We may spend with profit a short time in stock-taking. Let us examine for a moment the growth of a *Tribolium* population and then attempt to relate briefly that growth to some of the ideas developed in this paper. Earlier it was mentioned that Bodenheimer divides the growth of *Drosophila* cultures into four consecutive periods: (1) Period of initial growth, (2) of rapid growth, (3) of oscillations, and (4) of contraction. Although we lack much real information about the factors causing these periods, we can apply them to flour-beetle populations as *descriptive* stages of a continuous time-cycle. As with *Drosophila*, the periods of initial and rapid growth in *Tribolium* are well summarized by the logistic curve. Gause (1931) has fitted the data of Chapman (1928) to a logistic with not unreasonable deviation. Assuming that this curve is a good smoothed description of the way a *Tribolium* population grows, certain deductions about the character of that growth may be made. Such rationalizations are stressed by Gause (1934) and, from a more empirical viewpoint, by Bodenheimer (1937). The latter has applied certain arithmetical computations to the data of Chapman that are designed to aid in understanding the gross intra-population dynamics. The experimentalist will recognize immediately that these calculations merely serve to emphasize aggregate or statistical pressures; usually they do not clarify the finer actual mechanisms and, at times, really obscure them by lumping a number of items together. An example of this is in order. Chapman (1931) has shown that during *Tribolium* culture growth there is,

> "First a steady increase in number of eggs present. After some days the first laid eggs begin to hatch and there follows an increase in the number of larvae, and coincidentally with the increase in larvae there is a decrease in the number of eggs present. The next stage is that in which the larvae commence to pupate and the pupa population increases simultaneously with a decrease in the population of larvae. The egg production again rises, and now pupae begin to hatch producing an increase in the adult population which eventually reaches a steady state, while larval and egg populations continue to fluctuate about a stable mean. These fluctuations are best explained by treating the larvae and adults as predators of the eggs, which are themselves being produced by the adults. Thus the first decrease in eggs takes place when the larvae hatch, and it continues, owing to the predatory action of the larvae, until the larval population is reduced by pupation, which, of course, allows the egg population to rise." (Quotation from Ford, 1937; p. 11.)

Here, certain mechanisms based on life-history data are camouflaged by statistical grouping. Thus, for this case, points of a smoothed growth curve based on total population census would obliterate these oscillations exhibited by the population components. But the statistical calculations are useful if (a) accepted with certain critical reservations plus knowledge of the biology of the species in question and (b) fitted to basically sound data.

Bodenheimer's calculations, summarized in Table 15, are based on cultures growing in terms of the periods of initial and rapid growth certain general conclusions are evident. For the initial period the imago population is small and, after an early spurt, the rate of growth lowers to essentially a constant point. This early spurt may reflect co-operative coactions such as were discussed under the initial population optimum. During the early growth period the environmental resistance (also from Chapman; the environmental check on increase) and the intensity of the struggle for existence are low. In part,

TABLE 15

Population trend and analysis of 100 days' growth of a Tribolium culture

(Computations of Bodenheimer, 1937.)

AGE (*days*)	*A* Total population	*B* Adult population	*C* Potential increase of population	*D* Actual no. of eggs per day	*E* Realization of the potential increase	*F* Environmental resistance	*G* Rate of growth	*H* Intensity of struggle for existence
0	16	16	—	—	—	0.0	—	—
10	568	15	858	802	934.	0.066	35.5	23.2
20	563	14	751	237	315.	0.685	1.0	750.
30	596	92	2468	168	0.068	0.932	1.1	2243.
40	760	35	9389	127	0.013	0.987	1.3	7221.
50	791	362	7769	344	0.044	0.956	1.1	7062.
60	844	373	20065	1040	0.050	0.950	1.1	17331.
70	1056	362	19421	1559	0.080	0.920	1.3	14938.
80	1138	364	19529	1722	0.088	0.912	1.1	17753.
90	1286	361	19421	2068	0.106	0.894	1.1	17655.
100	1299	357	19207	2106	0.109	0.891	1.0	19206.

at 32°C., and 75 per cent relative humidity in whole-wheat, sifted flour. Many of the entries in the table are obvious. Column C shows the total possible population fecundity; in Chapman's words the "biotic potential." Column $E = \frac{D}{C}$ and Column $F = 1 - E$. Column $G = \frac{\text{total population}}{\text{total population of previous census}}$ and Column $H = \frac{C}{G}$. If we examine the table this is an expression of the fact that cannibalism is not too severe. This is the period when the potential reproductive performance is nearest actual realization. As the population moves into the period of rapid growth, the imagoes soon reach their equilibrium and the increase of immature stages begins to slow down. The culture approaches its asymptote and the rate of growth stabilizes to a point where it merely maintains the population at essentially an even level. The environmental resistance and the intensity of the

struggle for existence have grown to a maximum. There is but a small increment of realization of the potential increase.

Not too much is known about the period of oscillations for *Tribolium* cultures. The general conception of such oscillations was developed by Volterra (1926) who phrased the so-called "laws" of population fluctuations: "Law of the periodic cycle"; "Law of the conservation of the averages"; and "Law of the disturbance of the averages." Certainly, nothing of this sort has been rigorously fitted to *Tribolium* populations. However, there is some experimental evidence to the effect that if excessive conditioning is kept from entering into the picture flour-beetle cultures do fluctuate about some equilibrium point. Chapman was not clear on this point in his 1928 paper. In a later paper (1933) he suggested that mass infection of cultures with a Sporozoan (*Adelina*, see Park, 1934a) caused oscillations. Ford (1937) says,

> "*Adelina* is parasitic in *Tribolium* larvae, causing their death during the instar immediately preceding pupation. Thus in parasitized cultures no adults are produced, and the population gradually declines owing to the natural death of adults and consequent failure to maintain the egg production. During this decline the populations of eggs and larvae fall into fluctuating rhythms which alternate with one another. Eggs are continually being produced thus *tending* to an accumulation of eggs. Meanwhile larvae hatch from the eggs, on the remainder of which they feed. There is here the mechanism of fluctuations between predator and prey . . . and such fluctuations were found to occur in both accidentally and experimentally parasitized cultures. The parasite, by removing the pupal and adult stages from the population, has the effect of once more starting the larva-egg fluctuation with which a *Tribolium* population commences" (pp. 11–12).

In my laboratory I have recently observed also that *Tribolium* cultures oscillate with time about an average. The magnitude and the interval of the oscillations is somewhat variable but, nevertheless, they appear as true population realities. This work is now in process of analysis.

The conditioning experiments offer information pertinent for the period of contraction. For this final period some of the channels through which contraction operates—lowered fecundity, aberration of metamorphosis, etc.—are known. As far as results to date go, the conditioned flour studies suggest that, if the flour is not frequently renewed, *Tribolium* through conditioning start limiting their future population as far back as the period of initial growth. This conclusion is based on data (Park, 1936a, 1938, 1938a, Park and Woollcott, 1937, Park, Miller and Lutherman, 1939) which show that even slight amounts of conditioned flour have deleterious effects on certain of the beetles' responses. Suffice it to say that a definite period of contraction is known for *Tribolium* and some of the essential causal factors have been studied.

Pearl (1927) pointed out that the population student, whether field, or laboratory, or human, is concerned with two biological processes ultimately; natality or the forces of reproduction, and mortality or the forces of death. Furthermore, the student is interested in the factors, not in regard to individual organisms, but as statistical end-expressions of the activity of total aggregations. Thus the population is rooted by its basic biological variables to responses that are meaningless when viewed in other terms. In short, through its integration the population emerges as a new unit; a unit that possesses its own set of activities, its own particular environment, and its own heredity. (For an elaboration of this point see Emerson, 1939 and Park, 1939.)

In a number of the studies reviewed thus far we have seen how the population size at any moment of time depends on the

balance between total reproductive potentialities and the check or resistance exerted by the environment on these capacities. This check or "environmental resistance" may act either on birth-rate or on death-rate. In a stimulating paper Smith (1935) proposed that environmental resistance be split into two major components; "density-dependent" and "density-independent" factors, thus following a suggestion proposed by Howard and Fiske (1911). This is a recognition of the fact, already abundantly attested in this paper, that density thresholds are created by a population as it matures and these thresholds control, in part, the population's life-history. Factors that operate in this way are density-dependent and include such examples as predator and parasite relationships, diseases, intra-specific population pressure, spatial restrictions, food limitations (in part), and so on. These factors vary in their effect on a population as that population varies its density. To put it differently, environmental resistance is modified, in one direction or another, by crowding. In the category of density-independent factors belong largely such elements as climate (see Uvarov, 1931). These factors contribute an increment to the total population environmental resistance which does not vary with density. Let us take a stylistic example. Imagine a population, 100 X, that has a total environmental resistance of 50. Of this resistance at a given instant of time 30 is density-dependent and 20 is density-independent. If 100 X changes by growth to 200 X the density-independent environmental resistance remains 20 but the density dependent resistance changes, say, to 72. This change is not predictable. It must be assayed.

There are certain suggestions that can be made about the Clements-Shelford system as applied to *Tribolium* populations. During the population's life-history the primary cycle is in continuous operation. There are always habitat actions on the beetles and beetle reactions on the habitat. Also, there is always aggregation and, by that token, always coaction in one or all of its aspects. These mechanisms, however, change in character, in mode of operation and in end-effect as the population matures in time and space. Thus the actions-reactions of the initial growth period are not necessarily the same as those in the period of rapid growth or the period of contraction. For example, during the latter period the action-reaction aspects of conditioning are of great significance as we have shown, while in the initial period they are not so important. Contrariwise, those reactions impinged by young populations on the flour that establish burrows and tunnels and other physical modifications are essential during the initial period but unimportant in the contraction period. However, both are population products and both are primary cycles. To that extent they play equivalent rôles in population control. As the population matures coactions shift in character and end-effect even more than do actions and reactions. Coactions are, of course, products of density and much more intimately linked with density-dependent factors than the action-reaction cycle. The latter, while it may be density-dependent in part, is frequently density-independent; that is to say, certain actions and reaction take place irrespective of crowding. This is not true for coaction. Environmental resistance is continually changing during a population's history and this change is caused largely by the dependence of coaction on density. The intensity of the struggle for existence is a case in point. It has been shown for cultures of microörganisms, *Drosophila*, *Tribolium*, and the honeybee

that this intensity, which is primarily an indicator of competition (although we may have co-operative and disoperative components), increases during the first two growth phases; fluctuates in causal relationship during the period of oscillation, and increases enough during the contraction period to initiate and continue the population's decline.

The reader will recognize two points: (1) that these controlling factors of the population are not mere dialectics; we have implemented many of them empirically and in considerable detail in this paper and future population research should permit greater implementation, and (2) that, with the important exception of migration, the basic forces operating in laboratory populations are a simplified counterpart of those operating in field communities. This last point is another way of saying that those concepts of Clements and Shelford discussed in this paper are comprehensive. They can be fitted to a diverse group of field communities as well as to experimental populations. Two questions suggest themselves to the critically minded biologist: (a) is there any advantage in this comprehensiveness, and (b) is it an artifact or an ecologic reality? I think the advantage lies in that the system gives the ecologist a working framework into which he can apportion diverse facts and thereby evaluate existing data, and, just as importantly, it enables him to recognize where the gaps in ecological knowledge lie and take steps to improve the situation. The concepts dealt with here are neither erudite nor abstruse. They are merely obvious ideas that aid in interpreting the environmental relations of organisms and their usefulness lies in this very point. As soon as ecology progresses further the concepts can be refined, or, if necessary, readily discarded. But in all events it is the *progress* in which we are interested!

Early in this paper it was suggested that there are operational similarities between the field and laboratory population. This point stimulates the experimental work since the latter has for its first biological aim the ultimate interpretation of natural, ecological phenomena. To me, the agreement between Clements' and Shelford's system and the *Tribolium* and *Drosophila* studies supports this contention. It would be unfair, however, not to point out in passing that there are some *differences* between field and laboratory populations. Two such differences are especially obvious: (1) laboratory populations are overly simplified, and (2) laboratory studies have not analyzed to any extent migration and dispersal phenomena which are of great significance in natural communities. The first difference is really a common but pointless argument against the validity of the experimental work. I fail to see any real distinction between the ecologist, analyzing experimentally a population process in order to gain more insight into group integration, and a physiologist, analyzing experimentally the contractility of an excised muscle in a foreign solution in order to learn more about the muscular co-ordination of the entire organism. The general failure of the population student to examine migration in his experimental system is an argument of greater weight. Until this factor is subjected to successful experimental analysis the laboratory population student cannot consider that he has concerned himself with all the basic similarities that exist between field and laboratory groups. Contrariwise, there is much that the field student can learn by applying the experi-

mental techniques developed in the laboratory over to field problems.

The final point to be discussed is the status of the philosophical position taken by Clements and Shelford. It will be remembered that they suggested that the community is a social organism and they held that this aided them in making their interpretations. After working through this material on the experimental population as an illustration of a general ecological system I find myself concluding (1) that the population or a community is such a social or supra-organism, and (2) that this interpretation adds something to an understanding of the population. To me the supra-organismic concept is more meaningful when applied, say, to social insect populations than to *Tribolium* or *Drosophila*. However, it does aid in focusing attention on the *unity* of the population by stressing the analogies or convergences between an individual organism and an organism group and by showing that this unity is in part a product of natural selection. Natural selection thus emerges as a common denominator regardless of the level of biological organization.

It may be appropriate to discuss further what is implied when the population is referred to as a unit. By unit I mean that the group emerges with certain tangible properties, both statistical and biological, not possessed by its components. We may express our meaning of unit in symbolic terms. Assume a population composed of a series of individual organisms symbolized as X. Each X has a complete set of biological attributes designated as Y. If the population does not behave as an integrated whole, a group *1000* X will have properties *1000* Y. However, there are abundant data to show that the Y component of *1000* X is not the simple sum *1000* Y but, say, *750* Y or *1237* Y. It is this *deviation* that emerges as a population property, a result of aggregation and subsequent organization of the aggregants. Obviously, there is nothing in the slightest new in this position. Morgan (1933, see also a review by Wright, 1935) and Wheeler (1928) and much earlier Spencer (1860) among others have made these suggestions. The essential point is that the ecologist or population student must focus his attention on the deviation since this is a true population characteristic. This is a helpful conclusion but I think it must be reached first by empirical analyses of the populations themselves with the supra-organismic analogy emerging secondarily. To my mind, the real value of the latter analogy is philosophical rather than technical. It aids in synthesizing a perspective in which biological groupings of different levels of complexity can be placed one with reference to the other.

SUMMARY

The primary concern of this paper is to show that laboratory populations and natural field communities have many biological and statistical similarities. This viewpoint is developed by (1) discussing critically certain major concepts of the ecological system of Clements and Shelford; (2) illustrating these concepts in some detail with experimental investigations taken from the literature dealing with *Tribolium confusum* and *Drosophila melanogaster* populations; and (3) synthesis of the material developed under points one and two.

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AVIAN HOSTS FOR MALARIA RESEARCH

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INTRODUCTION

EXPERIMENTS with avian malaria have contributed a great deal to our understanding of the life cycle of the human malaria parasite. In addition, the basic studies on chemotherapy of malaria have been carried out with birds, and have resulted in the discovery of the two best known synthetic drugs, plasmochin and atebrin.

No existing antimalarial drugs, however, have proven to be completely satisfactory. Moreover, the supply in this country of quinine, plasmochin and atebrin has been threatened by the blockade of the second world war. For this reason, an intensive program has been established in search for a new antimalarial drug which could be produced domestically. Consequently, avian hosts are playing an increasingly important role in malaria research in the United States.

The purpose of the present paper is (1) to discuss the avian hosts of malarial parasites available for laboratory use, (2) to point out their advantages and disadvantages as tools in malaria research, (3) to provide some information concerning the supply and maintenance in the laboratory of the duck which the author believes to be the most suitable host at the present time, and (4) to list the contributions to our knowledge of the biology of *Plasmodium* resulting from the study of this parasite in different hosts.

Canary

More than 130 species of birds are known to be infected in nature with the malaria parasite, *Plasmodium* (Manwell and Herman, 1935). From these birds, more than a dozen accepted species of *Plasmodium* have been described. Early investigators used wild birds as experimental hosts for malaria research. However, the presence of natural infections in such hosts often interfered with their experiments. It was, therefore, necessary to obtain a domesticated host raised under conditions which would preclude the possibility of natural infection with *Plasmodium*. The canary satisfied this need when it was found to be susceptible to *Plasmodium* by Koch (1899) and others. Until recently, the canary has been used widely and almost exclusively as an experimental host for avian malaria studies. It was a suitable host not only because it proved to be susceptible to most of the known species of *Plasmodium*, but also because it could easily be maintained under laboratory conditions.

However, Laveran noted as early as 1891, that the usefulness of the canary as an experimental host for malaria research is limited by its small size. With the development of modern methods of research, particularly with the use of the Warburg apparatus, the limitation of the canary has become even more apparent. This bird usually can not provide more than one

cubic centimeter of blood even if it is exsanguinated. The need for an avian host which could supply a large volume of blood is imperative for many of the *in vitro* investigations on immunity, biology, chemotherapy and cultivation of *Plasmodium*. Moreover, the *in vivo* studies of the malaria parasite in canaries, may be complicated by the fact that in the preparation of films the daily blood losses may produce anemia in such a small host.

Aside from the small size, the usefulness of the canary as an experimental host is limited also by its high cost and inadequate supply due to the fact that it has not been bred in this country on a large scale. Female canaries, which do not sing, cost much less than male birds, but even they are expensive. Moreover, the price of canaries has been doubled, and in some localities, tripled by the present war blockage. According to Jaquith (1941), the import of canaries from Europe, usually amounting to 175,000 birds annually, has been completely discontinued since February 1940. As a result, the bird dealers are looking for substitutes to be used as pets.

For the reasons listed above, attempts have been made by various investigators in this country to secure a large and inexpensive experimental host for the study of avian malaria parasites. Chickens, pigeons, and ducks have been tested for this purpose with relatively successful results reported in 1938 by Coggeshall, Coatney, and Wolfson, respectively.

Chicken and pigeon

Manwell (1933) found that of the five well-known species of avian *Plasmodium* tested (*P. cathemerium*, *P. relictum*, *P. circumflexum*, *P. rouxi*, and *P. elongatum*), none survived in chicks for more than 10 days after inoculation. Temporary infections with *Plasmodium* in chickens have also been reported by Coatney (1938) who used *P. relictum*, Wolfson (1940a) and Hegner and West (1941b) who used *P. cathemerium*. Brumpt (1935) described a new species of *Plasmodium*, *P. gallinaceum*, from a wild fowl of Ceylon, and later was able to maintain it in domestic fowls. A great deal of experimental work with *P. gallinaceum* has been reported from abroad, but this species is not available for study in the United States, since its import is prohibited by the quarantine law. More recently, Coggeshall (1938) successfully inoculated domestic baby chicks with another new species of *Plasmodium*, *P. lophurae*, which he isolated from a pheasant in the New York Zoological Garden. According to him, the number of parasites at the peak of infection may be high, but a large number of parasites in the inoculum is required in order to transmit the infection. For maintaining *P. lophurae* in the laboratory, frequent transmission from chick to chick is imperative. The inoculum must always consist of blood from an acute case, because the parasite can not be recovered from chicks during the latent period of the infection.

It has been generally believed that pigeons are not susceptible to laboratory strains of avian *Plasmodium*, since unsuccessful attempts to inoculate them were reported as early as 1899 and 1908 by Koch and Wasielewsky respectively. Wolfson (1937a) found that the wood thrush strain of *P. cathemerium*, generally maintained in canaries, produced an infection in pigeons which lasted for at least 46 days after the inoculation. Since then it has been learned by the author that although the number of parasites in the circulating blood of pigeons may be too low for a direct microscopic finding, pigeons harbor *P. cathemerium* for at least as long as one year and probably as long as they live. Several investigators, including Sergents

(1964), Ogawa (1912), Böing (1925), and Coatney (1938), have observed plasmodia in natural infections of pigeons. Coatney succeeded in inoculating a strain of *P. relictum* from a naturally infected pigeon into other pigeons experimentally, and has since maintained it in the laboratory.

Thus *P. lophurae* of chicks and *P. relictum* of pigeons are available for study in large experimental hosts. However, these hosts have the following limitations: (1) each of the hosts is known to be susceptible to only one species of *Plasmodium* which precludes comparative studies of different species in the same host; (2) no satisfactory insect vector is known for either of the two species; (3) *P. lophurae* produces only a transitory infection in chickens; (4) pigeons can not feed themselves during the first three weeks after hatching. In order to prevent the possible infection of squabs with *Haemoproteus* while they are in the nests, special screened cages have to be used for breeding pigeons. This special set up raises their price almost to the level of that of the canary.

Duck

The first attempt to infect the duck with *Plasmodium* proved successful (Wolfson, 1938). The wood thrush strain of *P. cathemerium* which was inoculated into the duck at that time has been maintained since then in this host. Later, the duck was found to be susceptible to *P. relictum*, *P. lophurae*, and *P. elongatum* (Wolfson, 1939, and 1940b). As is the case with the canary, the susceptibility of the duck to the different species of *Plasmodium* is different in degree. Likewise, the rapid transmission of the parasite through the duck increases the duck's susceptibility. The course of the infection of the four species (five strains) of *Plasmodium* in the duck is summarised in Table 1. Most of the 250 ducks included in this table were of the Pekin breed under 2 weeks of age (weighing less than 100 grams) at the time of the inoculation. No prepatent period occurred in infections with any species of *Plasmodium* after the intravenous inoculation with a large dose of parasites. When the doses were small, the prepatent period lasted up to one week after the inoculation. The length of the patent period was less than 2 weeks in all species with the exception of *P. lophurae*. In *P. lophurae* it lasted up to three weeks, but usually terminated in the death of the host before that time. The highest number of parasites in the circulating blood of the ducks at the peak of infection did not exceed 4,000 per 10,000 erythrocytes in three species. In *P. lophurae*, however, the number of parasites per 10,000 erythrocytes usually reached 10,000 and sometimes became as high as 19,000. The lowest number of parasites at the peak of infection was observed in *P. elongatum* and the matinal strain of *P. relictum*. In both of these, the number of parasites did not exceed 500 per 10,000 erythrocytes. In *P. elongatum*, at times more parasites were found in tissues, particularly the bone marrow, than in the circulating blood. Therefore, the number of parasites in the blood of birds infected with *P. elongatum* was not a true indication of the severity of this infection. It is clear from Table 1, that the susceptibility of the duck to *P. lophurae* is greater than to any other species thus far studied.

Further studies showed that the duck exhibits no age immunity to infection with *P. lophurae*. Table 2 illustrates the course of the infection in three ducks of different weights and ages which were inoculated simultaneously with an equal number of parasites per gram of weight. In the adult Pekin duck (6 months old), weighing 6.3 pounds (1750 grams), the number of parasites on the sixth day after the

inoculation reached the usual 10,000 per 10,000 erythrocytes. However, even when the infection was very high, for example in a Muscovy duck weighing 280 grams (Table 2), only 80 per cent of the red cells of the circulating blood were found to be infected, with each cell containing 3 to 4 parasites on an average.

TABLE 1

Four species of Plasmodium in ducks

SPECIES	NUMBER OF BIRDS USED	PATENT PERIOD IN WEEKS	HIGHEST PARASITE NUMBER PER 10,000 r.b.c.
P. cathemerium.....	131	1–2	4,000
P. relictum			
capistroni strain.	8	1 or <1	1,500
matinal strain...	60	1 or <1	500
P. lophurae.....	29	1–3*	19,000
P. elongatum.....	22	1	500

* Infection usually terminates in death of the host.

TABLE 2

Plasmodium lophurae in ducks of different weights

TIME AFTER INOCULATION	NUMBER OF PARASITES PER 10,000 RED BLOOD CELLS		
	1750 *grams*	580 *grams*	280 *grams*
30 minutes	100	160	120
12 hours	140	160	180
4 days	2,000	1,500	2,200
5 days	7,000	7,500	7,800
6 days	10,000	10,400	10,000
7 days	Dead	Killed	19,300
8 days	—	—	—
9 days	—	—	6,000
10 days	—	—	Dead

The duck exhibits definite age immunity to the other three species of *Plasmodium* studied. However, after recovery from an acute infection the duck seems to harbor the parasites as long as it lives. It has been possible to keep three ducks infected with *P. cathemerium* for at least one year after inoculation. One duck infected with *P. elongatum* has been kept for 10 months after inoculation. At the end of these periods all ducks were still found to be infected. Occasional relapses several months after inoculation have been observed in ducks infected with *P. cathemerium*. However, no systematic study of relapses has been made.

Embryos

Unsuccessful attempts at cultivation of avian *Plasmodium* in egg embryos have been reported on several occasions. The first report on the subject is probably that of Huff and Bloom (1935) who injected canary embryo with *P. elongatum* "in order to determine whether the primitive blood cells and primitive erythroblasts should harbor these parasites." Similarly, negative results were obtained on three other occasions when *P. gallinaceum* of chickens was injected into chicken embryos (Gavrilov, Bobkoff, and Laurencin, 1938; Chorine, 1938; Rita, 1940). On the basis of these negative findings, Rita proposed a hypothesis that some fundamental changes must take place in the embryo at hatching, thus rendering the bird susceptible to *Plasmodium* to which it had not been susceptible before hatching. However, positive results of cultivation of *Plasmodium* in egg embryos published by other investigators tend to destroy the basis for this hypothesis.

Wolfson (1940b) reported successful cultivation of three species of *Plasmodium* in 14-day-old duck embryos inoculated with infected duck blood. In embryos infected with *P. cathemerium* no parasites were observed for 7 days after inoculation. Later a considerable number of them could be found in the blood. When blood films from a single embryo were studied on four different occasions, a few parasites were found on the 7th day after the inoculation, 500 parasites per 10,000 erythrocytes on the 8th day, 2,000 parasites per 10,000

erythrocytes on the 11th day, and 1,500 at death, on the 12th day. One embryo inoculated with *P. elongatum* was found to contain more than 3,000 parasites per 10,000 erythrocytes 7 days after inoculation. This exceeded several times the number found in the peripheral blood of ducks infected with this species. Duck embryos seemed to be less susceptible to *P. lophurae*. No parasites were found in the blood of embryos during 15 days after inoculation with large numbers of *P. lophurae*. However, a few parasites were observed at hatching. *P. cathemerium* prefers immature erythrocytes, whereas *P. lophurae* prefers mature cells. It is possible, therefore, that the degree of susceptibility of the duck embryo to the different species of *Plasmodium* is directly proportional to the degree of preference of the parasite for immature erythrocytes.

Shortt, Menon and Iyer (1940) successfully inoculated a 14-day-old chick embryo with sporozoites of *P. galinaceum*. At hatching, when the chicken was dead, a "moderate" infection was observed in the erythrocytes of its heart blood. In addition, a large number of exoerythrocytic stages were found in the liver, spleen, bone marrow, and particularly in the brain.

On the basis of the evidence existing at present, it may be concluded that at least three species of *Plasmodium*, *P. cathemerium*, *P. elongatum*, and *P. lophurae*, can be cultivated in duck embryos. Whether *P. gallinaceum* can be cultivated in chicken embryos by inoculation of infected blood is uncertain, but its cultivation can apparently be accomplished by inoculation of sporozoites.

Tissue culture

Huff and Bloom (1935), succeeded in maintaining *P. elongatum* in the culture of infected canary bone marrow for 48 hours, but *P. cathemerium* under the same conditions gave negative results. Gavrilov, Bobkoff, and Laurencin (1938), reported a survival of *P. gallinaceum* for 10 days in culture of infected chicken bone marrow. Hegner and Wolfson (1939) were able to maintain the wood thrush strain of *P. cathemerium* in culture of canary lung and spleen for 8 days.

In recent unpublished experiments the author has been able to maintain the wood thrush strain of *P. cathemerium* in the lung culture of two canaries for 14 days each, and that of one duck for 7 days. In one of these canaries, exoerythrocytic stages were observed at autopsy, in the other canary (inoculated from a duck) and in the duck, no such stages could be found at autopsy.

Thus far, three species of Plasmodium have been successfully maintained in tissue cultures. *P. elongatum* in canary bone marrow (2 days), *P. gallinaceum* in chicken bone marrow (10 days), and the wood thrush strain of *P. cathemerium* in canary lung (14 days) and in duck lung (7 days).

Advantages of the duck over the canary, chicken, and pigeon

The duck, like the canary, is susceptible to several species of avian *Plasmodium*, each of which produces a sufficiently high and lasting infection to be useful in experimental work. The advantages of the duck over the canary are numerous. At the time of hatching the duck weighs more than twice as much as the adult canary, and provides proportionally more blood than does the latter. Since ducks can be obtained directly from the breeder immediately upon hatching, their age and history can be ascertained with ease and accuracy. It is usually impossible to determine the history of canaries because they (1) are not marketed for several months after hatching and (2) are usually sold by the dealers rather than by the original breeders. If necessary, the sex of

ducks can be determined, whereas the sex of canaries, if they do not sing, can be definitely established only at autopsy. Finally, there is an ample supply of ducks in this country and their cost is less than one quarter of the pre-war price of canaries.

The advantage of the duck over the chicken and pigeon lies partly in the fact that the duck is susceptible to more than one species of *Plasmodium*; besides, *P. lophurae*—the only available parasite of chickens—produces a much higher and more lasting infection in the duck than it does in the chicken. Age immunity to *P. lophurae* which is marked in the chicken does not exist in the duck. Furthermore, the leg vein of the duck is conspicuous, so that the parasites can be inoculated into it with ease. An additional advantage of the duck over the pigeon lies in the fact that, like the chicken, the duck can be secured immediately upon hatching and therefore is certain to be free from infection previous to experimental inoculation. The pigeon, on the other hand, can not feed itself for the first three weeks after hatching. While in the nest, it is exposed to infection with *Haemoproteus* and possibly *Plasmodium*. The breeding of pigeons in specially provided screened cages raises their cost to four times that of the ducks.

The problem of insect vectors of *Plasmodium* should also be considered. The final test of any antimalarial drug is its ability to cure, and particularly, to prevent infection which in nature is transmitted by the insect vector. It is, therefore, important to know the vectors of the laboratory strains of *Plasmodium*. Mosquito vectors are known for most of the well-established species of *Plasmodium* residing in canaries. No such vector is known at present for the strain maintained in the pigeon. Likewise, no satisfactory vector has been found for *P. lophurae* in chickens. Laird (1941) found that *Aedes albopictus* fed on infected ducks developed sporozoites of *P. lophurae*. But these sporozoites inoculated into new ducks did not produce an infection as severe as is usually caused by the inoculation of trophozoites from the blood. The other three species of *Plasmodium*, known to infect ducks, are the same species and strains as have been studied in canaries, and their transmission has been accomplished on numerous occasions. *Culex pipiens* has been successfully used by the present author in transmission of the wood thrush strain of *P. cathemerium* and the capistrani strain of *P. relictum* (Wolfson, 1936, 1937b). *P. cathemerium* has also been transmitted by *Culex pipiens* from canary to duck (Wolfson, 1940a). Huff (1932) reported the susceptibility of several species of *Culex* mosquitoes and *Aedes triseriatus* to *P. elongatum*. Thus the mosquito vectors are known for at least three species of *Plasmodium* residing in the duck.

Finally, only the duck embryo was proven to be susceptible to the species of *Plasmodium* available for study in this country. *Plasmodium* can be maintained in cultures of duck tissue as well as in that of the canary.

Breeds and breeding seasons of ducks

The breeds of domestic ducks are discussed by Jull (1930) and Lee (1933, 1937). Of the 11 standard breeds existing, 10 are descended from the wild mallard (*Anas boschas*); the eleventh, the Muscovy, is sometimes considered to belong to a different species (*Anas moschata*). Only the Pekin breed of ducks is produced by the commercial duck farmers of the United States. The intensive commercial duck farming in this country began with the introduction of Pekin ducks from China in 1873. With very few exceptions, all the

Pekins in this country are descended from the original 20 ducks. This fact is responsible for their uniformity. The Pekins are hardy, timid, docile, and fair layers. Since they are non-sitters, their eggs are usually incubated artificially. The Muscovy ducks, infrequently bred by general farmers, are comparatively poor layers. Because of the difference in size of the duck and the drake, they are not as well suited for marketing. In addition, being good flyers, they can easily fly over ordinary poultry fences and therefore, are difficult to raise. The Pekin breed is, therefore, the most popular with commercial and general farmers.

The breeding season of ducks is adapted to the demands of the market and the convenience of the breeders. According to Lee (1933), on large commercial farms, ducks are hatched in the winter or early spring, forced for rapid growth, and marketed at 9–13 weeks of age. Ducks which are produced on general farms, are usually hatched in the spring and marketed in the fall or winter at the age of 5–7 months. The regular hatching season of ducks begins in December and extends through May and into June. A local general farmer, although breeding ducks on a small scale, has been able to provide young ducks and fertile eggs for this laboratory all the year round with the exception of the two autumn months, September and October. According to him, during that time the number of eggs layed by his flock was not large enough to make it profitable for him to run the incubator. But this year he increased his flock and therefore expects to have a supply of ducks all the year round.

The weights of ducks

According to Jull (1930), the following are the standard weights for the adult ducks: Pekin duck = 8 lbs.; drake = 9 lbs.; Muscovy duck = 7 lbs.; drake = 10 lbs.

The weight changes in the growing ducks depend on the diet used and the amount of exercise allowed. Horton (1928) reported the weight changes of Pekin ducklings beginning with the egg at the time of incubation and ending with a 12-week-old duck. He gave the average weight of 2.01 ounces (35 grams) for ducklings when they hêtched. His figures expressed in grams are as follows: At the end of 1st week = 44 gr.; 2nd week = 98 gr.; 3rd week = 227.5 gr.; 4th week = 401.5 gr.; 5th week = 560 gr., and so on. On the whole, normal ducks kept in the laboratory show similar changes in weight.

The blood picture of ducks

A thorough investigation of the normal blood of the domestic ducks was reported by Magath and Higgins in 1934. They were dealing probably with the Pekin breed of ducks referring to them as "tame mallard." Of eight ducks used by them, three were males and five females. The amount of hemoglobin was found to be 15.6 ± 0.35 gr. per 100 cc. of blood. The number of cells = 3,065,000 ± 32,000 per cubic millimeter. The length of the erythrocytes varied from 9.9 to 13.4 microns with 11.2 as an average; the width from 5.9 to 8.9 microns with 6.7 as an average. The values for the length and the width of the nucleus are 5 to 7 microns by 1.5 to 2.5 microns. The erythrocyte count is given as 3,065,000 ± 32,000, reticulocytes representing 20.7 ± 0.67 per cent. The leucocyte count was found to be 23,400 ± 811, of which 24.3 ± 0.33 were polymorphonuclear (with eosinophilic granules), 61.7 ± 0.41 lymphocytes, 10.8 ± 0.34 = monocytes, 1.5 ± 0.5 basophils. The mean thrombocyte number was computed to be 30.706 ± 703.

Maintenance of ducks, duck embryos, and tissue cultures in the laboratory

The suitability of ducks as experimental animals is not generally known since they have not been used until recently. Several requests have been directed to this laboratory for information on how to take care of ducks, and particularly, how to provide water for swimming.

In this laboratory ducks have been used since 1938. Their maintenance does not require any provisions different from those used for chickens. For more than two years, the birds have been kept successfully in any type of cages available. These were usually old rat cages. Electric heaters placed near the cages provided the additional heat required by ducklings under two or three weeks of age. Regular brooders equipped with heating elements have also been used and have naturally been found to be more satisfactory. The daily care given to ducks consists in supplying them with drinking water and food (chicken mash). Several times a week the cages are thoroughly cleaned. Unlike the Muscovy, the Pekin ducks have a "quack" which is heard when they are hungry.

Ducks thrive without swimming; but they like to dip themselves in drinking water (as do canaries when supplied with drinking water in containers placed on the bottom of the cages). If wet and chilled, ducks develop pneumonia and die. Therefore water containers used for duck cages should be such as to prevent the birds from getting wet. Regular brooders eliminate this difficulty. Ducks should not be given ice cold water to drink, since it causes an acute indigestion and produces death within a few minutes. Common diarrhea may occur in ducklings at a very early age due to over-feeding, over-heating, chilling, or ice cold drinking water. To treat this condition, Hunter (1935) suggests that the birds be given a teaspoonful of bicarbonate of soda to each quart of drinking water for one day. This treatment may be repeated after two or three days if necessary, but the pens should be thoroughly cleaned after each treatment. According to Hunter, the ducks are subject to very few of the many diseases common to most poultry.

Embryos of Pekin ducks have been successfully maintained in this laboratory at a temperature of 100 to 105 degrees Fahrenheit. The humidity in a 60-egg electric incubator fluctuated between 50 and 70 per cent. In addition, the eggs were dipped daily in lukewarm water. The incubation period of the Pekin duck egg (28 days) is one week longer than that of the chicken egg (21 days). Since the duck egg provides a longer period for the study of the parasites than does the chicken egg, the former is more desirable for the cultivation of *Plasmodium*.

Most of the tissue cultures of *Plasmodium* maintained in this laboratory were of the so-called "roller" tube type. The details of the technique used in preparation and maintenance of such cultures is given by Gey (1936). The essentials of such a technique can be summarized as follows. Small pieces of infected tissue are placed on the walls of the test tube and kept in position by coagulated plasma. Supernatant fluid added thereafter consists of balanced salt solution, embryo extract, and serum. This fluid provides nutritive material and is usually replaced every two or three days. The test tubes are held in a nearly horizontal position in a slowly rotating drum, and incubated at a temperature of 37.5 degrees centigrade. The rotation of the tubes causes the tissue to be intermittently bathed in the nutritive medium and exposed to the oxygen of the air.

So-called "hanging drop" cultures were

also used with a nutritive medium similar to that listed above.

Contributions to our knowledge of the biology of plasmodium by the study of parasites in different hosts

It is known that certain species of avian *Plasmodium* in canaries prefer reticulocytes to mature erythrocytes (Hegner and Eskridge, 1938). When some of these species of *Plasmodium* were inoculated into the duck, it was found that such preference persisted. This indicates that it is not due to the species of host harboring the parasite, but rather to the innate nature of the parasite itself. *P. cathemerium* and *P. relictum* in canaries as well as in ducks prefer *immature* erythrocytes, whereas *P. lophurae*, whether residing in the chick or in the duck, prefers *mature* erythrocytes.

Recently a new, exoerythrocytic, stage in the life cycle of the malaria parasite has been described from birds and was reported to occur in man. Exoerythrocytic stages found in association with all the species of avian *Plasmodium* except *P. elongatum*, are believed to represent an additional, perhaps "incidental," cycle independent from the erythrocytic cycle. Exoerythrocytic stages found in canaries infected with *P. elongatum* are believed to represent a part of the cycle in the red cells, and to be necessary rather than incidental for the persistence of the erythrocytic infection in this species (Parker and Huff, 1940). When *P. cathemerium* and *P. elongatum* were transmitted from canaries to ducks, it was found that the exoerythrocytic stages of *P. elongatum* persisted in the ducks, whereas the exoerythrocytic stages of the wood thrush strain of *P. cathemerium* which were always found in canaries apparently disappeared in the ducks (Wolfson, 1940a, b). Similarly, exoerythrocytic stages found in penguins infected with *P. relictum* (Rodhain, 1938), disappeared when the infection was transmitted to canaries. Thus the presence of exoerythrocytic stages of avian *Plasmodium* other than *P. elongatum* depends on the species of host.

The basic criterion for the differentiation of the species of avian *Plasmodium* is morphology. When *P. cathemerium* and *P. relictum* were transmitted from canaries to ducks certain changes in the morphology of these parasites were observed (Wolfson, 1938, 1939; Hegner and West, 1941a). The effect of the host on the morphology of *Plasmodium* could not be determined previously when studies on the morphology of avian *Plasmodium* had been carried out with the canary as the only host.

In addition to changes in morphology, Hegner and West (1941b) noted a possible change in the length of the asexual cycle in *P. cathemerium*, from 24 hours in the canary to 48 hours in the chick.

The difference in the virulence of *Plasmodium* in different hosts is quite conspicuous. This fact has been used by the author in keeping certain strains in the laboratory in less susceptible hosts, to avoid the necessity of frequent transmission. For example, the wood thrush strain of *P. cathemerium* is very pathogenic for canaries. It kills the host usually within two weeks after inoculation. The author has kept this strain in a duck thus saving the trouble and the expense of transmission until such a time when it is needed for research in canaries. Similarly, the author has kept in canaries *P. lophurae* which kills ducks. In canaries the infection with *P. lophurae* is mild, but the author found it to last for at least 15 weeks.

It has been generally believed that the periodicity of *Plasmodium* depends upon

the diurnal changes in the environment of the parasite and the host, such as the intake of food, muscular activity, and temperature. Since the environment of the egg embryo is more constant and can be controlled much more readily than the environment of the bird after hatching, the study of the periodic phenomena of *Plasmodium* in the embryo presents certain advantages. It has thus far been observed that the residence of *Plasmodium* in the embryo tends to increase the synchronicity of segmentation of the parasite (Wolfson, 1940b).

Tissue cultures are useful in the study of the life cycle of *Plasmodium*. Hanging drop cultures which permit the observation of the living tissue under the microscope can be employed for the study of processes of multiplication and penetration of the parasite into new host cells. Since red cells do not multiply in cultures, whereas the cells containing the exoerythrocytic stages may undergo such multiplication, the "roller tube" tissue cultures have been employed for the purpose of studying the relationship between the erythrocytic and the exoerythrocytic stages of *Plasmodium*. Although the results obtained thus far are not conclusive, they seem to indicate that erythrocytic and exoerythrocytic stages can undergo a change from one to the other, in cultures, in the vertebrate host, or in both. Cultures of infected duck embryo tissues may prove to be more suitable for the study of *Plasmodium* than have been cultures of tissues from older birds.

SUMMARY

Of four avian hosts available for malaria research in the United States canary, chicken, pigeon, and duck, the duck is believed to be the most suitable.

(1) Like the canary, the duck is susceptible to several species of *Plasmodium*, each of which produces a sufficiently severe and lasting infection to be useful for laboratory study. The chief advantages of the duck over the canary are its large size, low cost and adequate supply.

(2) Unlike the duck, the chicken and pigeon are each susceptible only to one species of *Plasmodium* available in this country. Moreover, even *P. lophurae* produces a more severe and lasting infection in the duck than it does in the chicken.

(3) The vector of *Plasmodium* residing in the pigeon are unknown, whereas, the vectors of at least three species of *Plasmodium* residing in the duck are known.

(4) Only duck embryos are thus far known to be susceptible to species of *Plasmodium* available in this country.

(5) Pekin ducks are grown commercially in this country on a large scale. They can be bred throughout the year even on small general farms.

(6) The normal blood picture of ducks has been investigated and reported.

(7) The maintenance of ducks and duck embryos in the laboratory presents no difficulty. *Plasmodium* in duck tissues can be maintained successfully in culture.

(8) Contributions to our knowledge of the biology of *Plasmodium* by the study of the parasite in different avian hosts are numerous.

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NEW BIOLOGICAL BOOKS

The aim of this department is to give the reader brief indications of the character, the content, and the value of new books in the various fields of Biology. In addition there will frequently appear one longer critical review of a book of special significance. Authors and publishers of biological books should bear in mind that THE QUARTERLY REVIEW OF BIOLOGY *can notice in this department only such books as come to the office of the editor. The absence of a book, therefore, from the following and subsequent lists only means that we have not received it. All material for notice in this department should be addressed to B. H. Willier, Editor of* THE QUARTERLY REVIEW OF BIOLOGY, *Department of Biology, Homewood Campus, The Johns Hopkins University, Baltimore, Maryland, U. S. A.*

SOME NOTABLE ESSAYS ON PROTOZOAN RESEARCH

Being a review of *Protozoa in Biological Research*, edited by G. N. Calkins and F. M. Summers. New York (Columbia University Press), 1941. Pp. xli + 1148. 9 x 6. $10.00.

By Willis H. Johnson, Department of Biology, Stanford University.

During the past century the "little animals" of Leeuwenhoek have figured prominently in biological researches throughout the world. Many students have studied the Protozoa simply to gain a better understanding of this group of organisms, but many more have used these forms in their researches as suitable material for the elucidation of general biological problems. This volume, according to the editors in their preface, is the result of "a discussion by a group of specialists assembled during the summer of 1937 at the Marine Biological Laboratory at Woods Hole, Massachusetts, for the purpose of ascertaining the best means to stimulate further research on these unicellular animals." If these organisms have turned out to be less "simple" than they were once considered to be, they are, and will continue to be, very useful organisms in the study of many biological problems.

The book contains twenty chapters written by as many recognized authorities in the field. The following list of authors and subjects will give a good idea of the scope and nature of this work: G. N. Calkins, "General considerations"; H. W. Beams and R. L. King, "Some physical properties of the protoplasm of the Protozoa"; R. F. MacLennan, "Cytoplasmic inclusions"; C. V. Taylor, "Fibrillar systems in ciliates"; S. O. Mast, "Motor responses in unicellular animals"; T. L. Jahn, "Respiratory metabolism"; J. H. Weatherby, "The contractile vacuole"; G. W. Kidder, "The technique and significance of control in protozoan culture"; R. P. Hall, "Food requirements and other factors influencing growth of Protozoa"; O. W. Richards, "The growth of Protozoa"; C. A. Kofoid, "The life cycle of the Protozoa"; J. P. Turner, "Fertilization in Protozoa"; L. L. Woodruff, "Endomixis"; T. M. Sonneborn, "Sexuality in unicellar organisms"; H. S. Jennings, "Inheritance in Protozoa"; F. M. Summers, "The Protozoa in connection with morphogenetic problems"; E. R. Becker, "Certain aspects of pathogenicity in Protozoa"; W. H. Taliaferro, "The immunology of the parasitic Protozoa"; Harold Kirby, Jr., "Relationships between certain Protozoa and other animals" and "Organisms living on and in Protozoa".

In one group of chapters the nature of protoplasm, its organization and reorganization, is discussed from various angles. The introductory chapter contains brief discussions of the ecology of the Protozoa and of the history of protozoology, but the major discussion is concerned with

the problems of reorganization. Calkins speaks of a *fundamental organization* such as is found in a cyst or in an egg, characterized by undifferentiated protoplasm, and a *derived organization* which comes from the fundamental through metabolic activity and which is characteristic of the adult and all of its parts. The macronucleus, which is derived from the micronucleus, is described as the chief derived structure in ciliates. The renewal or reorganization of this important organelle is considered essential for continued vitality.

The authors of the second chapter state that while protozoan cells are the most highly differentiated of all cells, many of the differentiations are reversible. It should be added that in many of the Protozoa most of the differentiated structures are reversible. In this chapter a large number of researches dealing with the physical properties of protoplasm are reviewed. Such topics as the colloidal nature of protoplasm, surface properties, adhesiveness, density, optical properties, structural properties, and the effects of various agents on protoplasm are discussed.

A careful review of the diverse kinds of cytoplasmic inclusions which have been described in the Protozoa is given in the third chapter. A considerable confusion in the literature is indicated—a confusion in the names given to the different granules by different workers. These granules are difficult to classify either morphologically or on the basis of function. Many of these inclusions have counterparts in metazoan cells (mitochondria, Golgi bodies, etc.). The author takes the stand that these inclusions are formed "de novo" in the cells, that they are visible products of chemical reactions which occur in the cells. He states that "the cell is not restricted in the accomplishment of its functions by any system of universal and invariable cytoplasmic components".

The nature of fibrillar systems, parts of the derived organization, as known in four typical ciliates, *Paramecium*, *Stentor*, *Euplotes*, and *Vorticella*, is clearly outlined in Chapter IV. A survey of a number of other forms is given and the differences in the interpretations of the various workers is considered. In conclusion, Taylor, a pioneer student in this field, points out that some of the elements described may belong to the pellicle and that the fibrillar structures vary in function in different organisms, functioning in contractility in some, in conduction in some, and possibly in support in some.

The chapter on contractile vacuoles contains discussions of the origin, the structure and the function of these organelles. As described, contractile vacuoles form as a result of the activity of certain formed inclusions. In the formation of temporary vacuoles small vacuoles fuse; in permanent vacuoles droplets enter filling canals. The evidence on the function of these vacuoles is conflicting. Evidence is presented which indicates that they are organelles which prevent excessive dilution of the cytoplasm. It is also suggested that they may play a rôle in excretion.

The chapter on motor responses in unicellular animals is in many ways closely related to those just referred to. That the sol-gel, gel-sol changes which occur in the locomotion of an amoeba are tied up closely with the protoplasmic organization of the amoeba is recognized. That a clear understanding of the physical changes in the protoplasm involved in such movements is not yet at hand is indicated in this discussion. In this chapter Mast gives detailed discussions of the more recent investigations concerning the motor responses of the rhizopods, flagellates, ciliates and colonial forms to light, electricity, and chemicals.

Students interested in the general problem of growth will find the discussions in Chapters VI, VIII, IX, and X interesting. In Chapter VIII the various methods of sterilizing Protozoa are described in detail. The author rightly emphasizes the need for rigid bacteriological methods in pure culture studies and the need for standardization of the nutrients employed. Attention is called to the difficulties encountered in attempts to culture certain organisms in pure culture because they apparently require something from living sources. In this connection the problem of growth factors and vitamins in protozoan cultures is raised. As pointed out here, recent studies show that a number of substances act as growth factors or as growth stimu-

lants for certain unicellular organisms. The literature reviewed on this point indicates that this is a fertile field for future investigations.

A simplified classification of the Protozoa, based on their carbon and nitrogen requirements, is presented in Chapter IX. It is hoped that the classification outlined here will come into common usage. In this chapter the effects of the concentration of nutrients, the hydrogen ion concentration, the oxygen content, the redox potential, temperature and light on growth are discussed and many unsolved problems are pointed out. Population growth curves are discussed in both Chapters IX and X. A need for more detailed studies with pure cultures is indicated.

In a definition of growth the author of Chapter X states, "Growth is a fundamental attribute of living organisms, manifested by a change of size of the individual, or in the number of organisms in a unit of environment". It is gratifying to see the inclusion of the second part of this definition because usage justifies it. Many writers, however, have insisted that growth pertains only to an increase in size of the individual. Interesting methods of making counts and of measuring the volume of unicellular organisms are discussed in this chapter. It is suggested that the old problem of allelocatalysis should be reinvestigated using motion pictures, on the theory that the effect may be due to more swimming when the organisms are in large volumes of media.

The problem of growth is intimately related to the problem of respiratory metabolism. A well-written discussion of the general problem of respiratory metabolism and an attempt to link the general subject to protozoan work is found in Chapter VI. That relatively little work has been done on the subject is indicated by the author when he states, "it seems probable that in the near future we shall see the development of an organized account of protozoan respiration, and it also appears that this investigation will take place among investigators who are primarily interested in the Protozoa". The author paves the way for this work by (1) outlining and discussing the known methods of measuring aerobic respiration, (2) suggesting problems for solution in connection with a discussion of the effects of various substances on oxygen consumption, and (3) outlining the theories on the mechanism of respiration.

The chapters on the life cycle, fertilization, endomixis, sexuality, and inheritance are closely related. In Chapter XI, Kofoid, a veteran student of life cycles in the Protozoa, discusses two types of cycles. In one type, characteristic of primitive forms, there is an alternation of binary and multiple fission; in the other type there is an alternation of sexual and asexual reproduction. Attention is called to the fact that although sexual reproduction is not found among the primitive Protozoa it has evolved in this group and is characteristic of the higher Protozoa. The life cycles of the higher Protozoa, as of the Metazoa, include maturation, fertilization, cleavage, histogenesis, sexual dimorphism and gametogenesis. The emphasis placed on the unicellular nature of the Protozoa, according to the author, "tends to obscure their basic similarity in life cycle to that of the Metazoa, and thus to minimize the biological significances of the varied evolutionary accomplishments which have occurred in this primitive phylum".

A discussion of fertilization, as a part of the life cycle, is continued in Chapter XII. Numerous examples, illustrating copulation, autogamy and conjugation, are described. Such questions as, what is the real nature of the life cycle of the common amoeba, what is the rôle of the macronucleus in conjugation, are nuclei derived from chromidia, and numerous others, will suggest to readers of this chapter many problems for future research. In the following chapter, Chapter XIII, a clear discussion of the reorganization of the macronucleus in the Ciliophora, in intrinsic reorganization, in endomixis, in autogamy and in conjugation is presented. Woodruff questions Diller's conclusion that endomixis does not exist and presents evidence that both autogamy and endomixis occur in *Paramecium*. The facts presented here indicate that complete information on the nature of reorganization in *Paramecium* must await further research.

The discussion of sexuality, in Chapter

XIV, is based primarily on two genera, *Chlamydomonas* and *Paramecium*. The discussion of *Chlamydomonas* constitutes a good review of the numerous publications of Moewus on this genus. As is indicated here, Moewus has reduced what appeared to be a multiple sex system in this genus, through chemical analysis, to a dual system (male and female). Certain inconsistencies are pointed out in the work of Moewus. Because of the numerous criticisms which have been directed against these studies on *Chlamydomonas* the author of this chapter rightly suggests that this work is in urgent need of repetition. The discussion of sexuality in *Paramecium* is in part based on the author's own careful studies. The systems of mating types, as worked out for several species, are outlined and discussed. The author argues for a "multiple sex" system in ciliates rather than for a "male and female" system. Two kinds of copulation-conditioning factors are suggested: one functioning in bringing cells together, the other functioning in bringing together their nuclei.

Inheritance in the Protozoa is discussed in Chapter XV under the headings, uniparental inheritance, biparental inheritance in haploids, and biparental inheritance in diploids. In the treatment of biparental inheritance in haploids the researches of Moewus on flagellates are further reviewed. Jennings, the author of this chapter, cites examples from Moewus' studies which show that independent assortment, linkage, crossing over, sex linkage and sex inheritance occur in these organisms. He states that this work of Moewus has placed the genetics of Protozoa on a new footing; but at the same time he points out that Moewus' conclusion on crossing over, which is based on two-strand crossing over, is a serious difficulty and needs clearing up. The discussion of biparental inheritance in diploids is based on the work of Sonneborn, Jennings and their associates on *Paramecium*. It is shown that segregation of the diverse mating types takes place at the first fission following conjugation. Most of the clones are like one of the two parent types, but a few are different, unlike either parent type. The author states that, so far, this situation is unexplained. The discussion, here, of the relative rôles of cytoplasm and nucleus in inheritance is quite interesting. As a rule, in uniparental inheritance, racial or inherited characteristics are not altered, but Jennings points out that there are exceptions. Among such exceptions are the cases of degenerative changes resulting from unfavorable conditions which are inherited for long periods and cases of acclimation to chemicals and heat (Jollos' *Dauermodifikationen*) which may be inherited for hundreds of generations. The results of De Garis on size inheritance in *Paramecium* are compared with these cases. De Garis found that when individuals from a large race and a very small race conjugate, the offspring are like the parents for a number of generations, but after from 20 to 30 generations the nuclei exert their influences and the offspring have a common size. The effects of the cytoplasm in this case are of much shorter duration than in those described by Jollos. The author concludes that "the question whether inherited environmental modifications are exclusively cytoplasmic, or whether they affect the chromosomal material of the nucleus, must be left open for the present." However, the clear-cut experiment which he outlines to resolve this question will surely be carried out in the near future.

In the chapter on morphogenesis the rôles of various factors such as the external environment, stage in the life cycle, conjugation, encystment, degree of injury, size of fragments, and nuclei on regenerative processes are considered. Numerous interesting problems are suggested. This chapter, dealing as it does with the fundamental organization of protozoan protoplasm, might have been placed more logically with some of the earlier chapters.

The general nature of pathogenicity in the Protozoa is discussed in Chapter XVII. The author considers that the use of the three categories, commensals, symbionts and pathogenes, is highly artificial because there are no counterparts in the zoological scheme for these categories—there are no classes, orders, families or genera which have as their distinguishing character that they are pathogenic. In a discussion of several studies on *Endamoeba histolytica* and on *Plasmodium vivax* the author stresses the fact that within a given

species there are strains which vary greatly in their pathogenicity. This situation plus the great variation in the resistance of hosts to invading organisms are presented as primary considerations for investigators in this field.

In the following chapter an excellent and extensive account of protozoan immunity is presented. A description of the cellular and serological mechanisms of the host in protozoan immunity is followed by detailed discussions of immunity in malaria and in trypanosome infections. Taliaferro indicates that little success has been attained with artificial immunization in protozoan work. However, a number of useful tests which aid in diagnosis are described.

The relationships of Protozoa and other animals, usually considered under the categories of symbiosis, commensalism and parasitism, are discussed in Chapter XIX. Kirby prefers to refer to all of these relationships as symbiosis because the term, symbiosis, was so used originally by de Bary. Many cases of accidental and facultative parasitism are reviewed. The case of *Glaucoma*, which is used so much in laboratory studies and which has been found as a facultative parasite in several kinds of animals, is an interesting one. The evolutionary developments presented in the discussion of systematically related free-living and symbiotic flagellates and ciliates are quite instructive. Among the other subjects treated in this chapter are the question of host-specificity in connection with distributional host relationships, adaptations for attachment and for completion of the life cycle and the nature of the obligatory mutualism which exists with termites and their faunas of Protozoa. Kirby also contributed the last chapter which deals with parasites in Protozoa. This chapter will be interesting to many readers. Many cases of parasitism involving bacteria, fungi, and other protozoans are discussed. The author points out that these parasites of Protozoa have resulted in much confusion in the literature because they have been described by different workers as pellicular striations, supernumerary flagella, cilia and mitochondria. It is clearly indicated in this discussion that much remains to be done in this field.

When considered as a whole the book is well written. A few of the chapters are rather tedious to read largely because the authors, in their attempts to cover the literature in their fields, present page after page of abstracted material. In the preface the editors state that "our first real difficulty was to select a limited number of topics from a vast number of possibilities." To the reviewer it seems that only two serious omissions were made. Because so much emphasis is placed, and rightly so, on the organization and reorganization of the protoplasm of Protozoa in the first few chapters, a chapter on encystment and excystment, if included, would have made possible a more complete treatment of this subject. Also, since these unicellular organisms are so important in the general economy of nature, a chapter on the ecology of the Protozoa would have added to the value of the book.

This series of discussions will not only stimulate further research on the Protozoa but it will also facilitate such work in many ways. In most of the chapters a fairly thorough review of the literature, especially the recent literature, is given and in most instances the studies reviewed are evaluated and correlated. In each chapter literally dozens of problems for future investigation are outlined or suggested. For all workers in the field, and especially for beginning investigators, the very extensive bibliographies at the ends of the chapters will be quite useful. Wherever Protozoa are studied this volume will be invaluable for years to come.

BRIEF NOTICES

EVOLUTION

THE UPPER TRIASSIC FLORA OF ARIZONA. *With a Discussion of Its Geologic Occurrence, by Howard R. Stagner. Contributions to Paleontology. Carnegie Institution of Washington Publication No. 526.*

By Lyman H. Daugherty. Carnegie Institution of Washington, Washington, D. C.

$1.75 (cloth); $1.25 (paper). 11½ x 9; iii + 108 + 34 plates; 1941.

Stagner states that the leaf shales of the Blue Forest occur "below or interfingered with the less massive phases of the Newspaper Rock sandstone. . . . The field characteristics of these beds suggest deposition in a stream channel or estuary. The differences in composition, distribution, and structure of the bentonitic beds suggest a different mode of deposition for them," possibly lacustrine or subaerial deposits of volcanic ash.

The collections were made largely within the Petrified Forest National Monument near Holbrook, Arizona. The flora is represented by 6 classes, 11 orders, 35 genera, and 38 species, the dominant members being cycads and the Osmundaceae, the largest family of ferns. Descriptions are given of these different forms, and in a series of fine plates are shown the characteristic features. Preceding the descriptions there is a section on the topography, climate, and vegetation of this region at the present time and of conditions during the Upper Triassic. A list of 86 references and an index are provided.

WHEN THE WORLD WAS YOUNG. *By Martha McBride Morrel. Houghton Mifflin Company, Boston.* $3.00. 8⅞ x 5¾; xvi + 252; 1941

The origin and history of the earth with all its endowments and adornments has long fired man's imagination and curiosity, and tested his patience, skill, and ingenuity in piecing together the fragmentary fossil records of its past. The work of the archaeologist and the geologist has been richly rewarded, in that we now have a fairly clear idea of the age of the earth, as well as numerous activities, both animate and inanimate, that have occurred on or in the earth since its birth.

In a delightfully simple style, the author has incorporated into this fascinating book many scientifically accurate facts concerning the origin of the earth and the origin and evolution of life upon the earth. No attempt is made to include detailed and documentary evidence of these facts. Rather, the whole topic is developed in story fashion, and is written in language understandable to everyone. A bibliography and an index are provided.

GENETICS

HANDBUCH DER ERBKRANKHEITEN. *Band 2: Die Schizophrenie, by Berthold Kihn and Hans Luxenburger. Band 3: Die erbliche Fallsucht; Der Erbveitstanz (Huntingtonsche Chorea); Der schwere Alkoholismus, by Klaus Conrad, J. L. Entres, Ferdinand A. Kehrer, Friedrich Meggendorfer, and Kurt Pohlisch. Edited by Arthur Gütt. Georg Thieme Verlag, Leipzig.* Each volume: RM. 19.50 (cloth); RM. 18.00 (paper) (outside of Germany). [For subscribers to set of 6 volumes price reduced to RM. 18.00 (cloth); RM. 16.50 (paper).] 9⅝ x 6½; Bd. 2: viii + 336; Bd. 3: x + 454; 1940.

The preoccupation of the Nazi political philosophy with racism has given a great impetus to studies on human genetics. However, as has been sometimes the case with reference to the Eugenics movement, the investigations reported have been characterized by an enthusiastic desire to pass to immediate positive action rather than to contribute definitive knowledge about the biological foundations of diseases. These two volumes illustrate to some degree this attitude. For each of the conditions discussed, a section is devoted to the consideration of the legal measures that have been or could be adopted to outbreed it, for the purpose, of course, of improving the well being and health of the race. Volume 2 of this series concerns schizophrenia. In the first section Kihn describes in great detail, following accepted lines, the clinical manifestations and course of the disease, and evaluates the effects of the newer therapies advocated. Luxenburger reviews the data on the familial concentration of schizophrenia and schizoid personality. He brings out the difficulties in attempting to state psychic status of the relatives of schizophrenes or schizoids. He notes especially the discrepancies in the familial incidence rates reported by some

authors (he has limited himself to German data). While accepting the view that the disease or diseases grouped under the term schizophrenia have an inherited constitutional basis the author does not definitely assume that the hereditary transmission follows a particular Mendelian mechanism. A similar conclusion can be attributed to Conrad who, in Volume III, studied the hereditary factor in epilepsy. For this disease Pohlisch describes the clinical and pathological manifestations in great detail. Of especial interest is the attempt by both authors to classify what are the clinical and pathological traits that differentiate the several types of epilepsy discussed in the literature. In this same volume Huntington's chorea is discussed from the clinical standpoint by Kehrer and from the genetic side by Entres. In their respective sections these authors present a full and detailed review of the information available about this disease but add nothing new to the existing knowledge. Also in this volume Meggendorfer examines data from the literature, as well as his own, on the medical, pathological and genetic aspects of alcoholism. This is one of the most extensive summaries of the knowledge on the subject that has appeared. The author concludes, contrary to the opinion of many, that alcoholism is disgenic and consequently harmful to the race.

The exhaustive treatment of the several subjects included in these volumes, superior to other works so far published on diseases and inheritance, makes this series of *Handbücher* useful even though the occasional references to views we associate with the Nazi ideals will be distasteful to many. In addition, one criticism to be made is the inadequacy of the bibliography consulted and mentioned.

GENERAL BIOLOGY

WILLIAM BYRD'S NATURAL HISTORY OF VIRGINIA *or The Newly Discovered Eden. Edited and Translated from a German Version by Richmond C. Beatty and William J. Mulloy. The Dietz Press, Richmond, Virginia,* $4.00 9 x 5⅞; xxviii + 109; 1940.

This work, originally printed in German in Bern, Switzerland, in 1737 "at the command of the Helvetian Society", was written to interest the Swiss in the colonization of America—specifically the tract of 180,000 acres in Virginia owned by William Byrd, the founder of Richmond. Byrd was interested in bringing over Swiss settlers primarily as a check to the Catholic French and secondly to promote diversified farming to break the one crop obsession of the English settlers in Virginia which he feared would lead to economic distress. Incidentally, it appears that Jenner's group (Jenner was the translator of Byrd's description of Virginia into German) was the only one to accept Byrd's invitation. This

> Description of Virginia, its climate, inhabitants, government, religious matters and religions, trade, cattle raising, price of provisions, as also of the species of money, fertility, fruits and vegetables, trees, uncultivated as well as cultivated, as also all sorts of species of plants, flowers, herbs and roots; likewise what sorts of wild and domesticated animals, fowls, as well as fish, crayfish and other animals are to be found in the land mentioned . . .

is an interesting addition to early Americana. We quote at random:

> *Buffalo* is an animal with a hump on its back, of an enormous and terrible size, has long curly hair, from which the Indians make many things, and Europeans mattresses. . . . The meat and fat from it are as good as that from our oxen, indeed probably better.
>
> One has also *foxes* in this land. They are grey, but do not smell as bad as the European variety.
>
> One may obtain splendid wine from Madeira (a Canary Island), which is very delicious, and also strong, and which is far better and more healthful than all our European wines, not only because of its agreeable sweetness but because of its soothing quality, as I myself have found out.

CONSERVATION OF RENEWABLE NATURAL RESOURCES. *Some Fundamental Aspects of the Problem. University of Pennsylvania Bicentennial Conference. By Raphael Zon, William S. Cooper, Gustav A. Pearson et al. University of Pennsylvania Press, Philadelphia* $2.50. 9 x 5¾; vi + 200; 1941.

It is encouraging to note that conserva-

tion of our nation's resources is finally attaining a position of importance. From this series of papers by men in responsible government agencies, in institutions, and in other positions concerned with the problem, it is evident that the nation is cognizant of its responsibility to the future. The trial and error methods of the pioneers, with the ruthless policies of waste and indifference, are past, and now that the country is suffering from this ravaging the time is ripe for constructive efforts.

These papers are limited to the plant world and the topics are divided into three main categories: first, the use of natural vegetation as a guide to agricultural and forestry practice; second, climatic cycles in relation to the theory and practice of conservation; and third, the administrative task of conservation.

Grasslands, prairies, soil, and streams have never attained the major rôle in our broader conservation measures that the forests and wild animals have attained. That they are fundamental to any policy of conservation (not merely in the sense of preservation) and that agriculture should work in conjunction with, rather than destructively against, these plant communities is the keynote of the first subgroup of topics. Following papers deal with solar cycles, dendro-chronology, climatic pulsations, etc., and their bearing directly or indirectly on conservation. The final section contains papers dealing with the responsibilities of the States and of the Federal Government with regard to this problem. Together, these papers form an important and reassuring contribution toward saner and better methods for the preservation of our natural resources.

MARINE PRODUCTS OF COMMERCE. *Their Acquisition, Handling, Biological Aspects and the Science and Technology of Their Preparation and Preservation.*

By Donald K. Tressler, in Collaboration with Ward T. Bower, E.D. Clark, et al. Reinhold Publishing Corporation, New York. $12.00. 9 x 5⅝; 762; 1940.

A reprint (unchanged) of a volume which first appeared in 1923. In spite of its economic aspect the book contains much useful material for the biologist, and especially for the biochemist. Within its covers is gathered a great deal of information that can only be found elsewhere by referring to many different sources.

Several of the early chapters are devoted to marine salt, iodine, potash, algae, agar-agar, and alginic acid. Then follow sections on pearls, corals, characteristics of marine fishes, fish and liver oils, the shell fish, turtles and terrapins, whales, seals, walruses, and sponges. Aside from these subjects being treated from the commercial point of view there is a great deal on the life history, habitat and population of marine forms, their chemical properties, food value, etc. Lists of references conclude each chapter, and there are 257 figures and 90 numbered and many brief unnumbered tables in the text. In Appendix I are tables showing the statistics of the fisheries in the United States, by states; and in Appendix II is given a list of the common names (with descriptions) of the marine fish and animals of commercial importance of the United States and Alaska. An author index and a detailed subject index conclude the volume.

BIOLOGY WORKBOOK.

By B. B. Vance, C. A. Barker, and D. F. Miller. Edited by W. R. Teeters. J. B. Lippincott Company, Philadelphia. 92 cents. 10¼ x 7; iv + 316; 1941 (paper).

This high school manual is designed to make the pupil independent of constant direction, and provides an integrated problem-solving and comprehensive test program intended to fit the interests, needs, and abilities of the average student. It may be used with any standard textbook in high school biology, and specific page references to twenty of the commonly used high school texts in biology are listed at the beginning of each unit. Employing the unit-problem organization of subject matter, the work-book is organized into thirteen units. Each of these is divided into unit-problems which serve as the basis for student's classroom study, discussion,

and laboratory work. Included are projects, hobbies, field trips, extra assignments, outside readings, reports and other pupil activities. All activities point toward the practical side of science instruction. The order in which the units are arranged can readily be changed to suit the individual instructor, and enough material has been included for a complete school year. The book is profusely illustrated with well-chosen photographs and line drawings. There is no index.

GENERAL BIOLOGY. *Revised Edition.* *By James W. Mavor. The Macmillan Company, New York.* $4.00. 9¼ x 6; xxx + 897; 1941.

The present edition of this text largely overcomes the criticisms directed at the first edition (cf. Q.R B., vol. 12, p. 92). The author has inserted at the end of most chapters a list of references specific to the preceding discussion. Although the original illustrations have been supplemented by a number of new and distinctive photographs, the volume still remains below par in this respect. Further major changes are the inclusion of a discussion of ecology, the addition of new material on the physiology of vertebrates, and revision of descriptions concerning the life cycle of plants. There has been slight change in the final section, which remains an excellent discussion of general biological principles. Having lost none of its original clarity and good organization, this book by its revision has been raised above the ranks of the average fundamental biological text. It contains appendices giving phylogenetic surveys of the plant and animal kingdoms and a detailed index.

BIOLOGICAL SYMPOSIA, *Volume II. Speciation. Defense Mechanisms in Plants and Animals. Biological Basis of Social Problems. Regeneration.*

Edited by Jacques Cattell. With a Foreword by George A. Baitsell. Jacques Cattell Press, Lancaster, Pennsylvania. $2.50. 9⅜ x 6¼; [8 unnumbered] + 270; 1941.

The species problem today appears, as it has in former years, to hold the master key to evolution. Until early in the present century the greatest handicap to biologists was the lack of knowledge of the details of the relationship of one generation to another. This relationship is now emerging with the rapid advances of genetic and cytological research. It is with this problem of speciation, influenced by modern research, that this first symposium of the series deals.

The second symposium is on the defense mechanisms present in plants and animals. The third treats of the biological basis of social problems and the fourth and last is on regeneration. The bibliography following each paper, although short, is well selected and will serve as a guide to further reading on the problem discussed.

FOUNDATIONS OF BIOLOGY. *Sixth Edition* *By Lorande L. Woodruff. The Macmillan Company, New York.* $3.75. 8⅜ x 5½; xvii + 773; 1941.

This sixth edition of Woodruff's fine text has been thoroughly revised. Material has been added to all chapters, especially those on plant structure and function, and animal coordination and development. Endocrinal coordination has been assigned a separate chapter and a chapter on human ancestry has been added.

The fundamental problems of biology embracing the large problem of life common to both zoology and botany, are brought together in brief form. The author believes that the general biological viewpoint is the most favorable means of approach, both to a broad knowledge of living phenomena as part of a liberal education and to more advanced studies in zoology and botany.

BIOLOGY AT THE UNIVERSITY OF RICHMOND. *By John W. Bailey. University of Richmond, Richmond, Virginia.* $2.50. 9 x 5¾; 194; 1939.

In this interesting little volume, the present head of the Biology Department of the

University of Richmond has recounted all the activities of the department from the time of its inception in 1903 to the time the book was written in 1939. The growth of the department from one instructor and a half-dozen students to the present staff of three full-time professors and six student assistants, and an annual enrollment of over fifty students is indicative of sound growth under able leadership.

The author's habit of keeping detailed records of the activities of his department has resulted in a volume that will be welcomed by alumni and friends of the University of Richmond.

NATURE NOTES.

By John Kieran. Doubleday, Doran and Co., New York. $1.50. 7½ x 5; 112; 1941. Not an intensive study but short anecdotes to each topic contained in his book briefly sums up John Kieran's Nature Notes. Kieran lovingly presents his friends to the unscientific as well as to those better versed in nature lore. To those who study nature and nature's creatures these essays furnish delightful reading, and those who just admire birds and flowers for the pleasure they afford the eyes will appreciate them more after reading this collection by radio's famed mental encyclopedia.

HUMAN BIOLOGY

LIFE AND LETTERS OF VASCO NÚÑEZ DE BALBOA *including The Conquest and Settlement of Darien and Panama, The Odyssey of the Discovery of the South Sea, A Description of the Splendid Armada to Castilla del Oro, and The Execution of the Adelantado at Acla.*

By Charles L. G. Anderson. Introduction by Ricardo J. Alfaro. Fleming H. Revell Company, New York, London and Edinburgh. $3.50. 8½ x 5⅝; 368 + 2 folding maps; 1941.

The conquistadores were on the whole a bad lot. Cortés, the libertine and uxoricide, was surpassed in cruelty and treachery by Ojeda, Ovando, and the illiterate Pizarro, so that today the memory of these men is hated by the mestizo and they are repudiated by the creole. Consequently it is refreshing to read in these pages of one who, although severe, was always just, and who recognized the claim of the aboriginal caciques to a rank equal to his own, who never forgot that he was their guest, and who always kept faith with them.

Concerning the early life of Vasco Núñez de Balboa nothing is known. Except for his participation in the Bastidos expedition his first appearance in history was when he stepped out of a cask in which he had been hiding as a stowaway on board a vessel carrying supplies from Espaniola to the mainland. At that time he was 37 years old. At the age of 44 he was beheaded on a fake charge of treason, the result of the jealousy of the perfidious Pedrarías.

In those seven short years he had not only stood "silent upon a peak in Darien," beholding a new sea, more vast in extent than any body of water that had ever before met the gaze of a white man's eye, but also had established the first permanent settlement of Europeans in Veragua, as America was then called, had brought back the first account of the empire ruled by the Incas, had rescued two expeditions from disaster, and had finally been appointed leader of one of these, not by imperial fiat, but by the votes of those who had become his partners in adventure. If anything further is needed to convince the reader that Balboa was several centuries ahead of his time, let him imagine the fate that today would meet the crew of even a civil expedition, to say nothing of a military one, who should resort to the democratic procedure of choosing their officers by popular vote.

Among those executed with Balboa was his companion Hernando de Argüello. Was this man by any chance the ancestor of the family that supplied governors of California not only under the vice regency of New Spain but also under the empire of Iturbide, and whose most celebrated member was Srita. Concepcion de Argüello, the heroine of the poem by Bret Harte? It is the unexpected occurrence of such names as this that have already acquired historic and literary connotations that lend a peculiar fascination to the study of history.

A tremendous amount of scholarly re-

search has gone into the compilation of this book, and the author is to be congratulated on having made such a significant contribution to the early history and settlement of the continent upon which we live. Among the numerous plates is an illustration of the famous "White Indians" of Panama.

THE TRUTH ABOUT LEIF ERICSSON AND THE GREENLAND VOYAGES.
By William B. Goodwin. Meador Publishing Company, Boston. $3.50. 9¾ x 5½; 445; 1941.

The author tells us that this book is the culmination of over thirty years study. The reader who finishes it is likely to put it down with the feeling that if he could have devoted so long a time to the study of one subject, he could have produced a much more convincing argument.

The author's thesis is that the site of Vinland of the sagas was the present Portsmouth Harbor, New Hampshire, and it may well be that it was, but the liberal use of such words as "if," "probably," and "provided that" which are generously sprinkled over the narrative tend to weaken the force of the argument and to beget doubts in the mind of the reader from Missouri (why does the author refer to Kentucky as the home of skeptic critics?). The author is also addicted to the etymologically hybrid word "mapographer." Cartographer is the generally accepted term. He also uses the ambiguous expression "and/or," a device to which recourse is had by shallow thinkers who are uncertain which of the two words expresses their meaning. It is borrowed from jurisprudence and has no place in a scientific work.

The most original feature of the book is a discussion of some rather mysterious stone foundations in the interior of New England which the author has been investigating. According to the sagas the Norse settlers always remained close to the shore, and these stone buildings must have been the work of another people. Among the Norsemen themselves was a tradition that in a still earlier period there were settlements in Vinland older than their own, which they attributed to Irish colonists. Celtic-speaking aboriginees, supposed to be the descendants of these early settlers, figure prominently in the sagas, and to these people the author suspects the stone foundations to be due, but has not as yet made a sufficiently detailed study to justify his conclusions.

The Norse settlement is perhaps the most fascinating and romantic chapter in American history, and a scholarly work dealing with what is known of it, elucidating the sources of information, and expounding the various theories advanced by different authorities, would fill a long felt need. But the present work, which incidentally has no index, no bibliography, and no documentation, only bears witness to a muffed opportunity.

THE INDIANS OF THE WESTERN GREAT LAKES 1615–1760. *Occasional contributions from the Museum of Anthropology of the University of Michigan No. 10.*
By W. Vernon Kinietz. University of Michigan Press, Ann Arbor. $4.00 (cloth); $3.50 (paper). 6 x 6⅞; xiv + 427; 1940.

This survey, based largely upon the material in the archives of Ottawa, Montreal, Chicago, Detroit, Ann Arbor, and Washington, D. C., but including also some material already published, contains much that is of interest concerning Indian tribes of the Great Lakes region at a period when they were not greatly disturbed by the presence of the white people. The beginning date, 1615, marks the time when the first explorers came in contact with a Michigan tribe, between Ottawa and Champlain on the eastern or northern shore of Georgian Bay, in 1615. Actually there was little contact with the Indians—aside from the Hurons who came to Michigan in 1650—before 1660, so that the material is largely a record from the year 1660 through the following one hundred years. The closing date of the survey, 1760, marks the capitulation of Canada by the French. Since the French were not especially interested in settling the land, and disturbed the Indians very little, the presence of the whites was not actually resented by the

Indian tribes until after the French lost control of the region.

Most of the material that Kinietz has collected has been taken from accounts by Frenchmen—missionaries, traders, and administrative officers— and concerns the following tribes: Huron, Miami, Ottawa, Potawtomi, and Chippewa. For each tribe there is much data on location, characteristics, dress and ornament, economic life, social life, and religion. Since, however, the records were left by people who were not writing for the historian, we are not furnished with well-rounded accounts on any one phase of Indian life, as the author points out. But the volume furnishes the student of ethnology and anthropology with much valuable material.

A scholarly work, well documented. In an appendix—Memoir concerning the different Indian Nations of North America, by Antoine Denis Raudot—will be found 45 letters translated from the French, the earlier ones dated around 1709–10, the later ones without dates. A detailed index is provided.

WINONA AND RIDGE RUIN. *Part I. Architecture and Material Culture. Museum of Northern Arizona Bulletin 18.*

By John C. McGregor. Plant Materials by Volney H. Jones. Skeletal Material by Katharine Bartlett. Northern Arizona Society of Science and Art, Flagstaff, Arizona. $5.25 (cloth); $4.75 (paper). 8¼ x 5; 313, 1941.

WINONA AND RIDGE RUIN. *Part II. Notes on the Technology and Taxonomy of the Pottery. Museum of Northern Arizona Bulletin 19.*

By Harold S. Colton. Northern Arizona Society of Science and Art, Flagstaff, Arizona. $1.75. 8¼ x 5; 75; 1941 (paper).

For the past twelve years, the members of the staff of the Museum have been studying the archaeology of the region about the San Francisco Peaks in the north central part of Arizona. Previous publications have dealt with stages of the history before 1000 A.D. The present study deals with foci contemporary with late Pueblo II and early Pueblo III of the Anasazi chronology, and carries the history to the period 1150–1200 A.D. It is concerned with an area of six square miles north and east of Winona Station, on the A.T. and Santa Fe Railroad, which presents a sample of the conditions to be found on the 800 square miles of the black sand area east of Flagstaff, if the whole area were studied intensively. The following subjects are discussed in order: dates, cultural stages, methods, pottery structures, ground and chipped stone, shell, bone and horn, basketry, textiles and wooden objects, food and other raw materials, and disposal of the dead. It is the firm belief of the writer that the ecology of the Winona-Ridge Ruin section was much different when occupied prehistorically than at present. The book is well illustrated and contains a complete bibliography and index.

In outlining prehistorical cultures in time and space, the archaeologist in the Southwest leans heavily on pottery for his clues, and Part II of this report is a careful and authoritative study of certain aspects of the ceramic technology of the Winona pottery. The author emphasizes that his present paper is but a report of progress made to date and is not to be considered as a complete study. Numerous helpful illustrations have been provided and a bibliography and index are appended to the volume.

GERTRUDE BELL.

By Ronald Bodley and Lorna Hearst. The Macmillan Company, New York. $2.50. 8⅜ x 5½; x + 260; 1940.

This biography of the remarkable Gertrude Bell makes extremely interesting reading. Born, in 1868, and reared in a Victorian world when the lives of English girls of the upper classes followed very rigidly a conventional pattern, Gertrude Bell chose, at the age of 17, to go up to Oxford. There she passed all her examinations with distinction and took a "brilliant first class in modern history." Then followed a period in the social life of her class where her beauty and interesting personality gave her an unusual position. Traveling in the Orient she met Henry Cadogen who had a profound influence on

her life. Under the direction of Cadogen, to whom she became engaged but owing to his early death never married, she commenced the study of Persian and Arabic. The year 1899 marked the beginning of her journeys in the desert. After a few expeditions covering the beaten tracks until she had become proficient with her Arabic, she set off with her own caravan. The fine work that she did in archaeology and topography in the years preceding the first World War gave her a high rank among explorers and brought her many honors.

During the war Gertrude Bell's labors were in quite another field. Her keen understanding of the Oriental mind and the strong ties of friendship which she had formed with powerful tribal leaders as well as with nomads of lesser importance made it possible for her to render valuable aid to the British Intelligence Service. Lawrence, although of a younger generation, was her devoted friend and worked with her during these years. Later she became Political Secretary of the Mesopotamian Government and had an important part in establishing the kingdom of Iraq and in making Prince Feisal of Hejaz king. With the lessening of the heavy responsibilities in the English service Gertrude Bell turned again to travel, to archaeology, and to the building up of the Baghdad Museum. Her death in 1926 in her adopted country brought consternation and grief to the desert people who had come to regard her as their most valued friend in their relations with the British Government.

FAMILY AND COMMUNITY IN IRELAND. *By Conrad M. Arensberg and Solon T. Kimball. Harvard University Press, Cambridge.* $3.50. 9¼ x 6; xxix + 322; 1940.

One of the most curious and at the same time significant commentaries on the present status of the social sciences is that more precise information is available about the customs and social behavior of African or Australian natives than about the groups which comprise our civilization. It is, therefore, small wonder that the uplifter and others of like breed have to date been unable to formulate an effective program of social progress. Being well aware of this, the authors have chosen to examine the social life and organization of County Clare in Ireland where they lived for two years or more. The observations on the familial, social and economic aspects of the people of this Irish county are here reported in detail and constitute the substance of the book. The impersonal and consequently objective evaluation of the social behavior of this Irish population brings out certain characteristics that reveal the multiplicity and complexity of the elements involved. The findings reveal that the social behavior of the population studied centers around, and is a function of, the family and community life particular to it. The contribution of these two institutions furnishes the broad directives of the mode of living of the individuals whose behavior is further determined by the social interactions that emerge from the relationships of (a) familialistic order, (b) age grading or generation, (c) sex organization, (d) local division of labor, (e) economic exchange. The demographic characteristics of the group result from the combined action of these variables. It may seem that no new light has been shed on the social characteristics of our civilization by the enumeration of the factors presumably involved, because the authors cannot as yet arrive at a quantitative measure of their respective influence. Nevertheless, the guiding idea behind this investigation and the analytical procedure employed represent a considerable advance in the methodology of social sciences.

FAMILY HOUSING AND FACILITIES: *Five Regions. U. S. Department of Agriculture Miscellaneous Publication No. 399. Consumer Purchases Study. Urban, Village, and Farm. By Hazel Kyrk, Day Monroe, Maryland Y. Pennell, and Edith Dyer Rainboth. Government Printing Office, Washington, D. C.* 25 cents. 9⅛ x 5¾; vi + 223; 1940 (paper).

FAMILY EXPENDITURES FOR MEDICAL CARE. *Five Regions. U. S Department of Agriculture Miscellaneous Publication No. 402. Consumer Purchases Study. Urban, Village, and Farm.*

By Helen Hollingsworth, Day Monroe, Margaret C. Klem, and Karl L. Benson. Government Printing Office, Washington. 30 cents. 9⅛ x 5¾; vi + 241; 1941 (paper).

FAMILY EXPENDITURES FOR AUTOMOBILE AND OTHER TRANSPORTATION. *Five Regions. U. S Department of Agriculture Miscellaneous Publication No. 415. Consumer Purchases Study. Urban, Village, and Farm.*

By Day Monroe, Dorothy S. Brady, June F. Constantine, and Karl L. Benson. Government Printing Office, Washington. 30 cents. 9⅛ x 5¾; iii + 272; 1941 (paper).

The housing conditions—number of rooms, facilities for water, heat and light, and sanitary conveniences—of families living in 20 small cities, 140 villages, and 64 counties of 12 farming sections of the United States are described in the first of these volumes. The second and third present data on expenditures for medical care and transportation, respectively, of families at different income levels in these same localities. All three are part of a survey made by the U. S. Bureau of Home Economics concerning the income and consumption patterns in five regions (New England, Middle Atlantic and North Central, Plains and Mountain, Pacific, and Southeast). Except for the Southeastern region for which Negro families are included, these reports are confined to families in which both husband and wife were native-born whites.

DRUMS AND SHADOWS. *Survival Studies among the Georgia Coastal Negroes.*

By the Savannah Unit, Georgia Writers' Project, Work Projects Administration. Foreword by Guy B. Johnson. Photographs by Muriel and Malcolm Bell, Jr. University of Georgia Press, Athens. $3.00. 9¼ x 5¾; xx + 274 + 24 plates; 1940.

This is the report of a survey of the beliefs and superstitions of Negroes living on the coast and sea islands of Georgia. Over 130 Negroes (including one named Cohen) in 21 communities were interviewed and their beliefs regarding conjurers, witches, spirits, etc. were elicited. The exact formulation of the questions asked is not given here but the replies of the interviewed and their reactions are described in some detail. The replies phonetically reproduced in the style and language of the interviewed constitute the substance of the book Apparently, as the subtitle and preface indicate, the objective of the survey was to determine what residues of native African superstitions are still present in the American Negro. The person responsible for the elaboration of the data has evaded the issue by not discussing the superstitions but refers only to the parallelisms recorded by students of African lore. Numerous parallelisms are uncovered, and so, taking the findings at face value one could assume that certain beliefs have persisted after three generations in contact with the European civilization of our country. On the other hand, some of the superstitions of the African natives are common to European peoples. It follows that the findings reported here will need further interpretation before their significance regarding the survival of customs can be properly evaluated.

THE INTEGRATION OF AMERICAN SOCIETY. *A Study of Groups and Institutions. First Edition.*

By Robert C. Angell. McGraw-Hill Book Co., New York. $2.50. 9 x 6; ix + 228; 1941.

The central question discussed in this book is whether or not the principal social groups into which our society can be differentiated are stable. That is, do they develop loyalty in the components of the group or express ultimate common values of American life? With this question in mind the author considers the organization and function of each of the following seven types of groups: capitalistic enterprises, struggle groups (labor unions, for example), governmental units, benevolent groups, families, churches, clubs, and associations. From the examination of these groups, Angell finds that their evolution to their present status has led them away from the local community. Few seem to stimulate concern for the common welfare, individual rather than common goals are emphasized, and agreement on the objectives for common action are not achieved. Therefore, the author believes that unless

the trend is checked it may lead to a complete disintegration of our society. As a remedy he suggests actions that will insure the persistence of our stock of common values and that will foster an increased understanding between the groups. Obviously the social evolution of the past century has altered the conditions which enter into some forms of social behavior. But are these changed conditions harmful for our society and social way of living? The evidence discussed does not really permit an answer to the question. Nor can a satisfactory answer be obtained without an elaborate analysis that takes into account the biological foundations of social intercourse, employs precise terminology, and is supported by factual evidence.

THE PLAINS INDIANS AND NEW MEXICO, 1751–1778. *A Collection of Documents Illustrative of the History of the Eastern Frontier of New Mexico.*

By Alfred B. Thomas. University of New Mexico Press, Albuquerque. $3.50. 10½ x 6¾; xv + 232; 1940.

The history of New Mexico from the time of its first pioneers to the middle of the nineteenth century was, with few exceptions, a continuous record of suffering on the part of the settlers from attacks by the Plains Indians—the Apaches, Comanches, Utes, Jumanos and Pawnees. Although much has been written on the relations between the Spaniards and the Pueblo Indians, who were easily subdued (there was only one Pueblo revolt), little attention has so far been paid to the rôle the Plains Indians played in retarding the colonization of New Mexico. From 1751 to 1778 the scene was dominated by two persons. Don Thomas Vélez Capuchín, Spanish governor from 1751 to 1767, and Medinueta, who governed from 1767 to 1778. The former succeeded in establishing peaceful relations between the Pueblos, colonizers and the warring tribes. His policy included the halting of French trade which had hitherto supplied the Plains tribes with guns and powder, establishing trade relations between the Spaniards and Indians, and threatening one tribe against another. Medinueta reverted to the earlier policies of organizing expeditions and raids against the Plains Indians in an effort to subjugate them. The major portion of this book consists of translations of the policies and reports to their governmental superiors by these two governors. The introduction of 59 pages, a survey of the frontier history of New Mexico, offers a background for these reports. The book is profusely annotated, and is equipped with a bibliography and an index.

SOCIAL ORGANIZATION OF THE GÃ PEOPLE. *By M. J. Field. Crown Agents for the Colonies, London.* 12s. 6d. 8½ x 5½; xiii + 231; 1940.

The Native Administrative Ordinance of the British Government was based upon the customs and needs of certain of the Gold Coast Colonies. It assumes that all of the natives can be governed by dealing through the chiefs of the tribes. When the ordinance was formulated it was not recognized that the Gã customs were essentially different from those of the other groups, and that they had no centralization of power. The attempt to remold the age-old Gã traditions to conform to the relatively new administrative policy has led only to destruction of order.

To assure an understanding of the difficulties involved, the writer has gone into considerable detail about the history and social organization of the Gã people. He describes first the customs which are common to the group as a whole, and second, how each town is an independent republic having its own peculiar organization. The book will command the interest of cultural anthropologists and, more important, of the administrators of colonial policy. The need for careful study of a people before formulating a plan for their government is strikingly presented.

MAN STANDS ALONE.

By Julian S. Huxley. Harper and Brothers, New York and London. $2.75. 8½ x 5⅝; x + 297; 1941.

Fifteen pertinent essays, written at various times between 1927 and 1939 and all pre-

viously published in various periodicals, comprise this volume by the well-known biologist and humanist. They present a continuity of style and of method. The author himself sees the unity of the essays in the fact that they were written in "that strange restless indecisive period during which an age was dying, but most of us were refusing to face the imminence of its dissolution." Huxley sees before him and the world the task of the formulation of a social basis for civilization on the foundations of a new world picture reflecting special biological knowledge of the human being in all his uniqueness. Titles of the essays are: The uniqueness of man; Eugenics and society; Climate and human history; The concept of race; The size of living things; The origins of species; Mice and men; The way of the dodo; The courtship of animals; The intelligence of birds; Science, natural and social; The analysis of fame; Scientific humanism; Religion as an objective problem; and Life can be worth living. Thoughtful readers will doubtless challenge many of Huxley's inferences and conclusions, but they will also find his discussions interesting, instructive, and stimulating.

I Was a Head-Hunter.

By Lewis V. Cummings. Houghton Mifflin Co., Boston. $3.00. 8 x 5¼; ix + 338; 1941.

Starting from Bogota the author travelled alone across the mountains to a tributary of the Orinoco, the Guaviare River in Colombia. There he joined a primitive tribe of head-hunting Indians, learned their mode of existence and married three of their girls. He participated in their warfare, hunting, travels, and tribal ceremonies. The report of his adventures is entertainingly written and contains much information on the habits of these remote Indians and of the local game animals. Detailed notes and a glossary are added.

University of Colorado Studies. *Series B. Studies in the Humanities, Volume 1, Number 3.* Containing the Following Articles: *The First Biography of an English Poet*, by Irene P. McKeehan; *Germanic Influence on Old French Syntax*, by Paul-Louis Faye; *An Unnoticed Abridgment of the Historia de Preliis (Redaction I²–I³)*, by S. Harrison Thomson; *A Noteworthy Contribution to the Study of Bede*, by Jack D. A. Ogilvy; *George of Podĕbrady and Bohemia to the Pacification of Silesia—1459*, by Otakar Odložilík; *The Leadership of the English Delegation at Constance*, by Allen duP. Breck; *Emperor Charles IV and Pope Innocent VI*, by Edwin J. Westermann; *AOI: Another Suggestion*, by Paul-Louis Faye.

University of Colorado, Boulder. $1.00. 10 x 6¾; 86; 1941 (paper).

Engineering Progress and the Social Order. *University of Pennsylvania Bicentennial Conference, N-B.*

By Frank B. Jewett and Robert W. King. University of Pennsylvania Press, Philadelphia. 25 cents. 9 x 6; 15; 1941 (paper).

ZOÖLOGY

British Graham Land Expedition 1934–37 Scientific Reports. *Volume 1. No. 1, The Biology of the Weddell and Crabeater Seals with a Study of the Comparative Behaviour of the Pennipedia, by G. C. L. Bertram; No. 2, The Life Cycle of Wilson's Petrel Oceanites oceanicus (Kuhl), by Brian Roberts; No. 3, The Breeding Behaviour of Penguins, with Special Reference to Pygoscelis papua (Forster), by Brian Roberts; No. 4, On Two New Species of the Hydroid Myriothela, by S. M. Manton; No. 5, Anoplura, by Theresa Clay; No. 6, Lower Crustacea, by J. P. Harding; No. 7, Sphaeroceridae (Diptera), by O. W. Richards.*

The British Museum (Natural History), London. No. 1: 15s., No. 2: 7s. 6d., No. 3: 5s., No. 4: 5s., No. 5: 2s. 6d., No. 6: 1s., No. 7: 1s. 12¼ x 9; No. 1: 1–139, No. 2: 141–194, No. 3: 195–254, No. 4: 255–294, No. 5: 295–318, No. 6: 319–322, No. 7: 323–326; Nos. 1–5, 1940, Nos. 6–7, 1941 (paper).

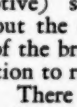
Important contributions to the knowledge of antarctic fauna are contained in this series. Bertram states, in his study of the Weddell and Crabeater seals (42 text-figures, 10 plates), that 367 of the former

and 177 of the latter were killed to provide food for the expedition, and that mostly the killing was in his hands. Conditions were rarely ideal for the complete examination of the bodies. Nevertheless the author succeeded in collecting a large amount of material bearing on the biology of these two species, the most abundant of the four species of Antarctic Phocids. Detailed studies were made on age, growth of foetuses and pups, skull development, and the ovaries. The report includes a section on the comparative behavior of the Pinnipedia, and in an addendum Bertram has arranged in condensed form, on a large folding chart, the main biological features of all the species of seals.

The second of these reports (24 text figures, 7 plates) gives much information on the taxonomy, breeding habits, migration, growth, etc. of Wilson's Petrel. The observations on breeding habits were made largely on a single colony, consisting of 23 nests in patches of moss. This colony was visited daily and the birds banded, the complete breeding cycle being covered for two seasons.

Limitation of space will permit only the mention of one other report in this series—The breeding behavior of Penguins (26 text figures, 4 plates)—which is the first of a series of studies on the Penguin data collected on this expedition. It is concerned chiefly with the Gentoo Penguin (*Pygoscelis papua*) and aims at "furthering knowledge of the responses which birds make to external (exteroceptive) and internal (proprioceptive) stimulation. The known facts about the characteristic behaviour phases of the breeding season are discussed in relation to recent advances in endocrinology." There is evidence that a "close correspondence exists between the cycle of internal changes in the mature bird and the sequence of activities which it is able to perform."

All of the studies in Volume I contain detailed reference lists.



THE LUNGFISH AND THE UNICORN. *An Excursion into Romantic Zoology.* *By Willy Ley. Modern Age Books, New York.* $2.75. 8½ x 5⅜; 305; 1941.

The subtitle of this work tells one exactly what to expect when we read it, and the reader will not be disappointed.

Prior to the period which the historians designate as the Renascence of Learning the acquisition of knowledge came about solely by the authoritarian method. The result was that error was accumulated along with truth. In the field of zoology a great body of folk-lore grew up in this way, which for lack of a better name might be called *Parazoölogy*. The popular superstition that elephants are afraid of mice, or that horse-hairs turn into snakes if immersed in water, are excellent examples of this sort of material, which is not unworthy of serious study, for it throws light on the cerebration of human beings in past ages. Such figments of the imagination as the unicorn, the dragon, and the basilisk are full of interest and romance, and after reading about them in this book the reader is likely to regret that the author did not include as well the sphinx and the centaur, the mermaid and the werewolf, the cockatrice and the manticore.

The second part of the book deals with animals that within historic times have become extinct, or nearly so—the native European cattle, the great auk, and the dodo. (Incidentally, the author makes no mention of the fresco of the last named bird on the wall of the monastery of Saint Catherine, which antedates the discovery of it by the Portuguese in the sixteenth century by upwards of a thousand years.) The present reviewer must confess that before he read this book he did not know the difference between an aurochs and a wisent. The author has a delightful literary style that allows him to change the subject as often as he pleases, which he does by making digressions to discuss the quagga, the Arctic manatee, the passenger pigeon, and the gigantic ratite birds of Madagascar and New Zealand, all of which disappeared only quite recently.

Finally, there is a discussion of living fossils—those peculiar forms that are the last surviving representatives of groups that belong to the past—the horse-shoe crab, the duck-billed platypus, the lungfish, and the peculiar lizards from the southern hemisphere with functional pineal eyes. That most romantic of all

living fossils, the chambered nautilus, has been overlooked, but this omission can easily be forgiven in view of the delightful entertainment the author has given us.

THE MIGRATIONS OF ANIMALS FROM SEA TO LAND.

By A. S. Pearse. Duke University Press, Durham, North Carolina. $3.00. 8½ x 5½; x + 176; 1936.

This is a well-written work on an important phase of ecology—the modifications which animals undergo when their environment is altered. The bibliography of 44 finely printed pages bears eloquent testimony to the painstaking research that has gone into its making. Yet it is not merely a digest of the printed reports of other people's work. The author himself has travelled extensively on four continents gathering material and checking up on the statements of others.

In the Cambridge Natural History published about half a century ago, the statement is made that many marine animals of the Indian Ocean have so adapted themselves to a fluviatile existence that they may be found in the Ganges river a thousand miles from the sea. The present author denies this statement, listing some of the same species by name, which he says have established themselves in the Ganges estuary, but are nowhere found in the river.

The work suffers from one serious defect —lack of proof-reading. A page inserted after the printing was done lists thirteen errata, mostly errors in spelling. The present reviewer has detected seventeen more, making a total of 30 in a book of only 186 pages. These are not all misspellings of scientific terms; many are the names of authorities quoted which are spelled one way in the text and another way in the bibliography. There is an old proverb that what is worth doing at all is worth doing well, and it may be that some readers may feel that since this book was not worth doing well it may not be worth reading. The reviewer would like to assure such readers that this book is really much better than its orthography would seem to indicate.

THE FISHES OF AUSTRALIA. *Part I. The Sharks, Rays, Devil-Fish, and other Primitive Fishes of Australia and New Zealand.*

By Gilbert P. Whitley. Royal Zoological Society of New South Wales, Sydney. 7s. 6d. 9½ x 6; 280; 1940.

This handbook is the first volume on the fishes of Australia and comprises the sharks and rays, as well as the lancelets, lampreys, and lungfishes. Succeeding volumes will consider the bony fishes.

Over one hundred species of these animals are listed and described, and nearly every form considered is illustrated by photographs or original drawings. The few facts known concerning the animal's life history, its range, and its relationship to man along with a more detailed and technical analysis for identification, are some of the topics discussed for each species. The writer has taken great pains to unearth many records of sharks attacking humans, and from a lengthy list of more or less substantiated records, he concludes that some species of sharks do attack men voluntarily and are not so harmless as some naturalists have claimed.

Other interesting topics such as an historical account of sharks, introduction to their anatomy, and especially an illustrated series of egg cases, all make this book a valuable contribution to a fascinating branch of ichthyology. Many myths are exploded, but facts stranger than fiction replace them. In view of the fact that sharks and rays assume a prominent position in the layman's mind, this book is recommended for authoritative information both from a scientific and a popular viewpoint.

THE AUDUBON GUIDE TO ATTRACTING BIRDS.

Edited by John H. Baker. Doubleday, Doran and Co., New York. $2.50. 7⅞ x 5¼; xviii + 268; 1941.

Almost all of the conceivable ways to attract birds and to provide for them are to be found in the chapters written by Roger T. Peterson, Richard H. Pough, John H. Baker, and Dorothy Treat that go to make up this guide for bird lovers. After preliminary chapters on bird study, photog-

raphy, and banding, Peterson explains how planting, artificial feeding, nesting boxes, and water can attract various species of birds and how these can be utilized in the most advantageous manner. Feeding birds consists of more than merely throwing bread crumbs on the ground, and providing nesting sites is more than knocking together any old kind of bird box. Consequently all those desirous of attracting birds—school teachers, home owners, or ornithologists—should first read this book and profit by the numerous suggestions and directions that it contains.

Wisely, there is a chapter on predators, and then to complete the book and enhance its value, there are sections on trespassing, maintenance of sanctuaries, bird attraction as an educational community project, and the individual's rôle in the protection of wildlife.

ZOÖLOGICA. *Scientific Contributions of the New York Zoölogical Society. Volume XXVI, Part 1, Numbers 1–12.*

New York Zoölogical Society. Zoölogical Park, New York. $2.00. 10½ x 7; 64 + 12 plates; 1941 (paper).

This number contains the following papers:

A new crayfish from San Luis Potosi, Mexico. (Decapoda, Astacidae), by Horton H. Hobbs, Jr. (1 text-figure); A new *Corydoras* from Brazil, by F. R. LaMonte; Notes on plumage changes in the Bald Eagle, by Lee S. Crandall (4 plates); External characters of six embryo nurse sharks, *Ginglymostoma cirratum* (Gmelin), by William Beebe (2 plates; 4 text-figures); A papillomatous disease of the gallbladder associated with infection by flukes, occurring in the marine turtle, *Chelonia mydas* (Linnaeus), by G. M. Smith, C. W. Coates, and R. F. Nigrelli (4 plates; 1 text-figure); Eastern Pacific Expeditions of the New York Zoological Society, XXIII. Polychaetous annelids from the west coast of Mexico and Central America, by Aaron L. Treadwell (21 text-figures); Plankton of the Bermuda Oceanographic Expeditions. X. Polychaetous annelids from Bermuda plankton, with eight shore species, and four from Haiti, by Aaron L. Treadwell (9 text-figures); Caudal skeleton of Bermuda shallow water fishes. V. Order Percomorphi: Carangidae, by Gloria Hollister (20 text-figures); Description of an egg of the Long-tailed Bird of Paradise, by Lee S. Crandall (1 plate); On the uterine young of *Dasyatis sabinus* (Le Sueur) and *Dasyatis hastatus* (De Kay), by C. M. Breder, Jr., and Louis A. Krumholz (2 text-figures); Additional social and physiological aspects of respiratory behavior in small tarpon, by Arthur Shlaifer; Notes on Mexican snakes of the genus *Trimeresurus*, by Hobart M. Smith.

INTRODUCTION TO GENERAL ZOÖLOGY. *By Nathan Fasten. Ginn and Company, Boston.* $3.75. 9⅛ x 5¾; viii + 742; 1941.

A new text for an elementary course in general zoölogy that is destined to find a useful place in the teaching of this subject. The author has arranged the material in three parts: Part 1 (8 chapters) deals with the animal organism—important problems and characteristics of living matter, protoplasm and its properties, theories of the origin of living matter, the structure, function and types of cell, reproduction, and classification of animals. Part 2 (17 chapters) is concerned with types of animals. In Part 3 (8 chapters) the development, adaptation, and relation of animals are discussed.

While the subject matter leads from the simpler to the more complex forms, provision has been made for those teachers who prefer to introduce the student first to representatives of one group and from that viewpoint approach the lower or higher animals. The volume is profusely illustrated, many of the figures having been especially prepared for the text. A bibliography of 8 pages, a glossary of 37 pages, and a detailed index conclude the volume.

PRINCIPLES OF ANIMAL BIOLOGY. *Fifth Edition.*

By A. Franklin Shull, with the Collaboration of George R. Larue and Alexander G. Ruthven. McGraw-Hill Book Company, New York and London. $3.50. 9 x 5¾; xiv + 417; 1941.

The present revision of this standard text (cf. Q. R. B., Vol. 5, No. 2; Vol. 9, No. 4 for mention of the 3rd and 4th editions) maintains the high degree of workmanship characteristic of the earlier editions. The most important changes to be noted are those relating to physiology. The rapid advance of knowledge in this field has required that substantial changes be made in the text with regard to the composition of the blood, the chemistry of muscular contraction, and the physiology of nerve impulses. The newer trends of biological pedagogy, i.e. emphasis on the study of function rather than structure of the living

organism, and the presentation of the individual as an integrated whole rather than a group of parts, have been carefully interwoven into the textual material. In contrast to the long list of standard texts which are organized around "type" organisms, the present one is developed along the broad lines of biological principles, concepts, and theories.

The text is profusely illustrated, and each chapter carries a list of references for supplementary reading. Present also are a 36-page glossary and a complete index.

ELECTRIC EEL CALLING. *A Record of an Artist's Association with a Scientific Expedition to Study the Electric Eel at Santa Maria de Belém do Pará, Brazil.*

By Shelby Shackelford. Charles Scribner's Sons, New York. $3.00. 9 x 6⅛; x + 258; 1941.

Mrs. Shackelford makes a live and colorful book out of the trip to the Amazon in search of the electric eel. While her husband, the physicist, and his associate, the biologist, explored this biological phenomenon, she, the artist, painted the ancient city of Pará and its inhabitants not only figuratively but also literally

The daily life of the investigators is dramatized through the eyes of an artist and philosopher, and is well portrayed not only in words but also by drawings which are original and well executed. However, this is not solely a novel, for the account of the researches on the electric eel are accurately described with the result that much material previously published only in technical journals is now made available to the general reader. Aside from the electric eel, the book is filled with tales of the local color of the Brazilian city, its environs, and the daily life of its people. This is indeed a fine book to read for both pleasure and profit.

BIOLOGY OF THE LABORATORY MOUSE.

By the Staff of the Roscoe B. Jackson Memorial Laboratory. Edited by George D. Snell. With a Chapter on Infectious Diseases of Mice, by J. H. Dingle. The Blakiston Company, Philadelphia. $7.00. 9 x 5¾; ix + 497; 1941.

An important volume for the experimentalist. The authors have gathered together the widely scattered literature on the mouse as a laboratory animal, filling in important gaps by special research projects. The book is designed especially as a reference work. Dealing only with the mouse it

> presents a vertical cross-section of biological knowledge rather than the more usual horizontal cross-section. It contains information about one animal drawn from various branches of zoology, rather than information about one branch of zoology drawn from observation of a variety of animals.

The chapter headings are as follows:

> The early embryology of the mouse; Reproduction; Histology; Spontaneous neoplasms in mice; Gene and chromosome mutations; The genetics of spontaneous tumor formation; The genetics of tumor transplantation; Endocrine secretion and tumor formation; The milk influence in tumor formation; Inbred and hybrid animals and their value in research; Parasites; Infectious diseases of mice; Care and recording.

Numerous tables and 170 figures accompany the text, and the work concludes with a bibliography of 341 titles and a detailed index.

FLEAS OF EASTERN UNITED STATES.

By Irving Fox. Iowa State College Press, Ames, Iowa. $3.00. 8⅞ x 5¾; vii + 191; 1941.

The medical importance of fleas in the transmission of disease is becoming increasingly recognized. The writer points out that no key to fleas has appeared since Baker's monumental work on *Siphonaptera* was published in 1904. The purpose of this work is to bring up to date the knowledge of fleas inhabiting the region east of the one-hundredth meridian, with the exclusion of Texas. Fifty-five species, falling into five families comprising thirty-three genera, occur in this area. They parasitize seventy-five mammalian and avian hosts according to our present knowledge. The fact that man and domestic animals fall within this sphere adds to the importance of the present publication.

The synonymic and host indices ap-

pended add to the value of the text. The work contains a selected bibliography and an index. Following the index are 166 excellent figures arranged on 31 plates.

A Revision of the Nearctic Hemerobiidae, Berothidae, Sisyridae, Polystoechotidae and Dilaridae (Neuroptera). *Proceedings of the American Academy of Arts and Sciences, Volume 74, Number 7.*

By F. M. Carpenter. American Academy of Arts and Sciences, Boston. $2.25. 10 x 7⅜; 88; 1940 (paper).

After examining something over 8,000 specimens of the five families of insects mentioned, the author has compiled this revision, which includes 14 genera and 66 species of Neuroptera. One genus and 17 species are described as new. In addition to the detailed keys to each family, the text includes such additional taxonomic information as distribution, habitat, natural history, and descriptions of the genitalia and wing venations of the various species.

A bibliography of 98 titles, a series of plates illustrating wing venations, and an index to families, genera, and species conclude the monograph.

Atlas of the Scale Insects of North America. *Series III, 269–384.*

By G. F. Ferris. Stanford University Press, Stanford University, Calif.; Oxford University Press, London. $7.75 (cloth); $6.75 (paper). 10¾ x 9; [236 unnumbered] + 116 plates; 1941.

This volume, the third of a series (cf. Q.R.B., Vol. 13, p. 360 for notice of the first) which is being prepared with the ambitious aim of describing every species of scale insect in North America, is devoted to 59 members of the Tribe Diaspidini and 57 of the Tribe Aspidiotini, both belonging to the Family Diaspididae. The excellent plates are the main feature of the book. A minimum of textual matter gives information on the distribution, hosts, habits, recognition characters and miscellaneous items to aid in the identification. The series is of primary interest to economic entomologists.

Bird Islands Down East.

By Helen G. Cruickshank. The Macmillan Co., New York. $2.50. 8⅜ x 5½; xii + 123; 1941.

The wife of a well-known ornithologist herein recounts the adventures with her husband among the offshore islands of Maine. To reach these islands is quite an undertaking in itself, and the struggles these bird students had against the waves and the fog give a salty marine flavor to the narratives. Naturally only sea birds are discussed, among these being puffins, petrels, gulls, guillemots, cormorants, terns, and phalaropes. The colonial life of the birds is well related and considerable information is given concerning the natural history of these small and practically inaccessible islands. Some of Mr. Cruickshank's most interesting photographs illustrate the book.

BOTANY

Amos Eaton. *Scientist and Educator 1776–1842.*

By Ethel M. McAllister. University of Pennsylvania Press, Philadelphia; Oxford University Press, London. $5.00. 9 x 6; xiii + 587; 1941.

"Noble Fellow" *William Starling Sullivant. With a Compilation of the New Species of Mosses and Liverworts Described by William S. Sullivant and Those Described by William S. Sullivant and Leo Lesquereux, Prepared by Richard T. Wareham.*

By Andrew D. Rodgers III. With a Foreword by Adolph E. Waller. G. P. Putnam's Sons, New York. $3.50. 8⅜ x 5⅜; xxii + 361; 1940.

These are well-written biographies of two leading botanists of the early 19th century who are not as well remembered by posterity as they should be. Although both of these men seem to have been on very intimate terms with John Torrey and Asa Gray, there is no evidence that they ever met. Sullivant was a specialist in the

narrow field of biology, but Eaton was a zoologist, a mineralogist, and a geologist as well as a botanist.

MacAllister treats the different phases of Eaton's activity separately, but this does not mean that Eaton took these studies by turns. All his life he was devoted to all branches of natural history, and although it is on account of his researches in systematic botany that he is chiefly remembered today, on one occasion he disavowed being a botanist.

He was a New Yorker by birth and descent, his ancestors having been among the original Dutch settlers of New Amsterdam, and it was in that state that most of his work was accomplished. The crowning achievement of his career was the establishment and development of the Renssalaer Institute in Troy, on whose faculty he taught for many years.

Sullivant, on the other hand, was a westerner. He was born in Ohio, when that was a western state, and his ancestors had been pioneers there for many generations. The first chapter of his biography is devoted to his genealogy. While exploring in the Northwest Territory he corresponded with all the leading naturalists of England and France, and the position which he finally achieved in the botanical world is indicated by the fact that the leading international bryological society bears his name—The Sullivant Moss Society.

Both books are well illustrated and indexed and have extensive bibliographies.

THE PLANT DOCTOR. *The How, Why and When of Disease and Insect Control in Your Garden. Revised Edition, with New Chapters on Regional Plant Troubles.*

By Cynthia Westcott. Frederick A. Stokes Co., New York. $2.00. $7\frac{3}{8}$ x $4\frac{3}{4}$; xx + 297; 1940.

This book is entirely different from any other garden book and should be in the possession of everyone interested in gardening. In a simple, yet entertaining style the author verbally takes the reader into the garden and, week by week, discusses and describes the insect pests and plant diseases that are apt to occur at that time, and the most effective methods of preventing and controlling them. Numerous black and white drawings illustrate and simplify the text.

After publishing the first edition of *The Plant Doctor*, the author spent four years traveling and studying plant pests and diseases in other parts of the country as well as in the Eastern States. Her observations are included in this revised edition. There is also a chapter on house plants, a condensed alphabetical miscellany, and a list of books recommended for additional reading.

TREE-RING ANALYSIS AND DATING IN THE MISSISSIPPI DRAINAGE. *With Appended Papers: Reflection of Precipitation and Temperature in Tree Growth*, by Mildred M. Wedel and Florence Hawley; *A New Dendrochronograph*, by E. J. Workman and Florence Hawley.

By Florence Hawley. Chicago University Press, Chicago. $1.50. $9\frac{1}{2}$ x $6\frac{1}{4}$; xi + 110 + 8 plates; 1941 (paper).

An introductory chapter describes the instruments and techniques employed in tree-ring work and an account of previous work in the Mississippi drainage. Then follows a detailed description of four seasons' work in analyzing tree rings of living trees, old logs and beams in order to obtain information on floods and droughts in the past, and of semi-decayed wood and charcoal from old Indian mounds and ruins to estimate their age.

A special technique for the preservation of mound specimens, especially charcoal, was developed for use by archaeologists and it is expected that certain dating of these specimens is possible and should be accomplished in the near future.

HILFSBUCH FÜR DAS SAMMELN UND PRÄPARIEREN DER NIEDEREN KRYPTOGAMEN. *Zweite neubearbeitete Auflage.*

By Gustav Lindau. Zweite Auflage by O. C. Schmidt. Gebrüder Borntraeger, Berlin. RM. 3.60. $7\frac{3}{4}$ x $4\frac{1}{2}$; vii + 93; 1938.

This pocket-size handbook contains gen-

eral directions for collecting, preserving and labelling specimens of cryptograms, and specific methods for the various species of fresh-water and salt-water algae, myxomycetes, fungi, lichens and mosses. Bacteria and the colorless flagellata, which cannot be studied by *Rucksack* methods, are omitted. Changes from the first edition include the incorporation of more recently perfected methods, the expansion of data on occurrence, and the addition of a bibliography. There is a subject index.

THE ANAEROBIC BACTERIA AND THEIR ACTIVITIES IN NATURE AND DISEASE. *A Subject Bibliography. Supplement One, Literature for 1938 and 1939.*

By L. S. McClung and Elizabeth McCoy. University of California Press, Berkeley. $3.50. 11 x 8; xxiv + 244; 1941.

Except for the creation of a section to cover the prophylactic use of toxoid in immunization and the citation of the complete title of each reference, this first supplement follows the general plan of the original volume (cf. Q.R.B., Vol. 15, p. 98). In addition to the literature for 1938 and 1939 some titles for 1940 have been included. A useful reference work. It is to be hoped that the authors will prepare further supplements.

PLANT ECOLOGY. *Third Edition, Thoroughly Revised.*

By W. B. McDougall. Lea and Febiger, Philadelphia. $3.00. 9⅛ x 5¾; 285; 1941.

This edition of an excellent text (cf. Q.R.B., Vol. 3, p. 141; Vol. 4, p. 366) follows the same general order of presentation as the earlier texts, with considerable space, as formerly, being given to a discussion of symbiotic phenomena. The many excellent figures form an important part of the text.

TROPICAL AMERICAN FERNS. *University of California Publications in Botany, Volume 19, No. 9.*

By Edwin B. Copeland. University of California Press, Berkeley and Los Angeles. $1.00. 10¼ x 6¾; 23 + 31 plates; 1941 (paper).

In addition to the descriptions of the ferns included in this list are interesting notes by the author discussing generic differences, distribution, etc. The fine photographic plates (31 in number) are, with three exceptions, illustrations of types.

MORPHOLOGY

PATTERNS AND PROBLEMS OF DEVELOPMENT.

By C. M. Child. University of Chicago Press, Chicago. $8.00. 9½ x 6½; ix + 811; 1941.

It is always pleasant to welcome a book based on a life-time of research that summarizes a field and collates loose ends. Such a book is Child's *Patterns and Problems of Development*. The axial gradient theory has been the subject of much debate among biologists for at least 40 years. Today, there are few workers who deny the existence of such gradients in many organisms. However, there are students, particularly the experimental embryologists, who view these metabolic gradients as mere expressions of some deep-seated activity and not as factors that regulate the *pattern* of growth and differentiation. Briefly put, the issue seems to be this: Can quantitative or rate factors, such as the gradients, initiate differentiation in a specific protoplasmic substrate, or, are there particular chemical substances or qualities produced within the organism that organize the protoplasm during early development with the gradients simply emerging as by-products of this organization? Child, of course, inclines to the former view and many embryologists to the latter. The problem is not yet settled. There are data that support both contentions. Be that as it may, Child advances in this book some cogent points in favor of his position. Also, his material has the virtues of good documentation with many examples and a point of view that is broad. The author conceives of development as something more than

the embryologic period. On this issue he says:

> Developmental physiology is often regarded as if it were concerned only with embryonic development, and for some authors of recent years it seems to be very largely a matter of vertebrate or even of amphibian development. It cannot detract in any way from the great interest and importance of the experimental work of Spemann, his students, and many others on amphibian development to point out that this and development of vertebrates generally constitute only a small part and, so far as fundamental problems are concerned, probably not the most important part of the field of developmental physiology. . . . There are many other forms of development, with other starting-points than eggs. Some of them, such as buds, reconstitutions of isolated pieces, and development of cell aggregates, bring us much nearer the beginnings of developmental patterns and the factors concerned in their origins and permit more extensive control and analysis than do most eggs and embryos. In fact, embryonic development appears generally to be the most highly specialized form of development. (page v.)

The book is organized somewhat as follows: first, the problem is delineated and the nature of gradients and the experiments that demonstrate them are discussed, using a wide range of material; second, the gradient theory is applied to a series of developmental problems, e.g., the "organizer" concept, cleavage, and the initiation of embryonic pattern; finally, the material is discussed generally in a chapter on physiological integration where the gradients are related to development somewhat in the causal fashion indicated above.

The book is admirably bound and documented. There are a number of fine drawings, an excellent bibliography and index, and a series of appendices concerned largely with methods.

This is an excellent comprehensive synthesis of the axial gradient problem and its implications and applications. It leaves certain points unsettled as the author readily recognizes and unquestionably there are statements with which certain biologists will disagree. But it is a tribute to the life work and ideas of a distinguished American scholar in the field of biological science.

DAS LABYRINTH. *Bau, Funktionen und Krankheiten des Innenohres vom Standpunkte einer experimentellen und vergleichenden Pathologie.*

By Cl. F. Werner. Georg Thieme Verlag, Leipzig. RM. 28.50 (cloth); RM. 27.00 (paper) (outside of Germany). $9\frac{3}{4}$ x $6\frac{1}{2}$; xvi + 400; 1940.

Probably no other organ of the body requires such specialized techniques of study as does the inner ear; so that, notwithstanding the importance of the ear for both hearing and equilibrium, investigations on the subject are today as before the prerogatives of only a few. Apparently aware of this the author has brought together the scattered information about the labyrinth in order to present an adequate summary of the recent and the established methods of investigation and the new discoveries about the function and the structure of this organ. Although sufficient mention is made of the diseases of the inner ear in man, emphasis is placed on the experimental approach to the study of the normal and pathological reactions of the cochlear and vestibular apparatus. In order, the author outlines first the techniques employed to examine clinically and experimentally the functional status of the ear. He then describes briefly the anatomy and histology, giving particular attention to the histological preparations. The chapters that follow describe fully the physiology of the labyrinth from observations and from experimental procedures. Among the latter, first place is given, of course, to the experiments based on the discovery of action currents. In the final chapters the effects of vitamins, of hormones, and of tumors are discussed.

The presentation is sound, detailed, and clear, and a very good list of references accompanies the text.

A LABORATORY GUIDE TO THE STUDY OF DEVELOPMENTAL ANATOMY.

By A. Byron Leonard. Burgess Publishing Co., Minneapolis, Minn. $1.50. $10\frac{5}{8}$ x $8\frac{1}{8}$; iii + 75; 1941 (paper).

This outline is intended to serve as an adequate guide for the student in a laboratory course in pre-medical embryology. The author, realizing that although draw-

ings frequently made by the student often require more time than the results justify, but believing that these student drawings frequently enable him to observe relations that might otherwise be missed, has here attempted a compromise—drawings have been reduced in number and in detail, while preserving the advantage of careful student observation. After suitable study of mitosis, meiosis, fertilization, spermatogenesis and oogensis, the outline proceeds to elaborate and concentrate on the various stages of the chick and ten-millimeter pig embryos. The series of plates, containing 142 carefully and completely labelled drawings, are especially commendable and constitute an important feature of the outline. The author has kept constantly before the student the concept that the developing organism is a discreet individual, with its own environmental problems presented for solution, even as the fully-developed organism has its problems of adjustment to environment. Space is provided for drawings and for lecture notes. Suggested reading references are placed at advantageous points in the book. There is no index.

TEXT-BOOK OF COMPARATIVE HISTOLOGY. *By Elbert C. Cole. The Blakiston Co., Philadelphia.* $4.00. 9 x 5¾; vii + 396; 1941.

In this completely authoritative and excellently prepared work, Cole has not only presented the subject from the logical, though somewhat neglected, comparative point of view, but has gone a step further to include the invertebrates as well in his pertinent discussion.

The textual material has been built up in four parts; namely, (1) a brief introductory section dealing with the history of the subject, the nature of the cell, the mechanics of cell division, and the origin of the various types of cells and tissues in the developing embryo; (2) a detailed study of the structure and function of the six fundamental types of cells; (3) a lengthy consideration of the body organs and organ systems as tissue complexes; and (4) a final short section on the care and use of instruments essential to the study of histology, and a list of accepted procedures in histological technique.

The volume is profusely illustrated, and each of the 22 chapters is supplied with a well-selected list of references. The complete index adds to its value for classroom or reference use.

COMPARATIVE CHORDATE ANATOMY. *A Laboratory Text. By Clair A. Hannum. Stanford University Press, Stanford University, California.* $2.00. 8⅜ x 5½; vii + 211; 1941.

This volume is designed for those courses of anatomy in which the empirical observations of the laboratory are subordinated to the broad generalizations that may be drawn from an assemblage of such observations. The present text follows the "type study" method of presentation, in which a variable number of representative chordates are utilized to illustrate the evolutionary processes that have culminated in the modern vertebrate. After suitable introductory material on the chordates, phyletic origins and ontogenesis, the following vertebrates are studied: balanoglossus, a simple ascidian, amphioxus, the fresh water lamphrey, the shark, necturus, the turtle, the pigeon, and the rat. The book is very carefully and completely indexed, but contains no illustrations or list of references. This laboratory text should be well received by those teachers using the "type study" method of instruction in comparative anatomy.

A LABORATORY MANUAL FOR HISTOLOGY. *By James Forbes. Fordham University Press, New York.* $1.25. 9⅛ x 5¾; vi + 74; 1941 (paper).

After proving its worth in the elementary histology course at Fordham University, this little manual is now ready for wider distribution and use. The work outlined is not intended to take the place of a textbook, but rather, to supplement any good text in the laboratory phase of the course. In addition to the required draw-

ings for each laboratory exercise, there are lists of questions designed to bring out the fundamental relationships between microscopic and gross structure, between structure and function, and between structure and development. The volume carries a short table of contents, and a list of references.

PHYSIOLOGY AND PATHOLOGY

NATURAL RESISTANCE AND CLINICAL MEDICINE.

By David Perla and Jessie Marmorston. Little, Brown and Company, Boston. $10.00. 9⅛ x 6¼; xx + 1344; 1941.

This monumental work leaves few pathways unexplored that lead toward an understanding of natural resistance to infectious diseases. It is a survey of the biology of natural resistance in health and disease and an analysis of the various factors that have a part in determining or modifying these conditions.

It was not many years ago that variations in resistance seemed to hinge on the virulence of the infecting micro-organisms, although individual variations seemed, possibly, attributable to "constitution." More recently it has been recognized that "such 'constitutional' differences while in part dependent upon genetic factors are to some degree expressions of the functional activity of the glands of internal secretion and that such variations definitely influence the course of infections." The possibility that the thyroid, thymus, the suprarenal and the sex glands, the spleen, the lymph glands, and the microphage tissue may all have some part in both natural and acquired resistance is now recognized.

The difference between natural and acquired resistance is clearly stated by the authors: "While acquired immunity depends upon the presence of antibodies and on an altered state of the tissues in their reaction to reinfection, natural resistance is dependent upon a different fundamental mechanism, modified by a great variety of biological factors."

The ten sections in the volume treat resistance from the following angles: heredity; age; sex; other endocrine glands; humoral and cellular mechanisms; liver, body surfaces and nervous system; diet; certain depression states; climate; and clinical aspects. Each of these sections has been summarized and concludes with a list of references, the total number of these titles running to something over 5,000. While recognizing the importance of the psychological and mental factors in resistance, the authors do not enter this field because "the evidence does not lend itself to critical analysis." Also the socio-economic factors, being outside of a biological treatise, have not been discussed, although the very great importance of this aspect is recognized.

A carefully prepared index concludes this useful survey.

THE STORY OF CLINICAL PULMONARY TUBERCULOSIS.

By Lawrason Brown. The Williams & Wilkins Company, Baltimore. $2.75. 8½ x 5½; ix + 411; 1941

This book, which embodies the lectures that Lawrason Brown delivered to his students, outlines the changes in the diagnosis and therapeutics of phthisis from the time of Hippocrates to the modern days of artificial pneumothorax In the classical manner, Brown divides the historical sequence into four periods: the first ranges from ancient times up to the middle of the 17th century; the second continues on to the beginning of the 19th century; the third, to the latter part of that century; and the fourth, from Koch's discovery to the present The knowledge and practices of each period are epitomized in an interesting fashion by an integrated description of the clinical procedures which were followed by the eminent physicians of the period. The figure of Laennec assumes gigantic proportions in this account as his contributions are restated time and time again. Brown had apparently a tremendous admiration for the French physicians and dwells at great length on their work. There are, however, also chapters on the progress manifested in this country, England, Germany, and Austria, and on the development of

artificial pneumothorax. To round out the subject, special chapters on the writings of Laennec, on the stethoscope, and on early medical journals are included. In addition, Sampson contributes a chapter on the diagnostic use of the x-ray in pulmonary tuberculosis, and Archibald discusses surgical treatment. Both of these chapters, as well as the previous sections, represent well-written, authoritative surveys of the subject, but the work, because of its fragmentary nature, cannot be regarded as history in the technical sense. It will, however, furnish the medical historian as well as the lay reader the means to evaluate the significance of the changes in the clinical handling of pulmonary tuberculosis.

A TEXTBOOK OF DIETETICS.

By L. S. P. Davidson and Ian A. Anderson. With Diet Sheets Constructed by Mary E. Thomson. Foreword by Sir John B. Orr. Paul B. Hoeber, Inc. (Medical Department of Harper and Bros.), New York. $4.25. 8½ x 5¼; xviii + 324; 1941.

The field of dietetics is at least one in which the general practitioner can carry out his double rôle of service in promoting health and curing disease. Up to the present time, however, it has been difficult for him not only to keep pace with the advance of knowledge in nutrition, but also to translate the results of animal experimentation into terms of human health and disease. In the face of these facts there has been a real need for a book which would present the latest knowledge of nutrition in such a form as to be of immediate and practical use to the practicing physician. The present volume has grown out of an abundance of experience in the dietary treatment of human ills, as well as from experimental work on animals, on the problem of nutrition.

The work covers such wide topics as the physiology of nutrition, diet in periods of physiological stress, and dietetic treatment in established diseases. Throughout the volume there is a plea for closer cooperation between the laboratory research worker and the general practitioner in the hope that the time lag between laboratory experimentation and practical application will be cut to a minimum. The volume is further enhanced by a group of tables, recipes, and diet sheets to be used by the physician in making his dietary recommendations in various diseases that are directly or indirectly affected by the nutritional state of the patient. The list of selected references and the complete index also contribute to the value of the book for the overworked general practitioner.

ENDOCRINOLOGY. *The Glands and Their Functions.*

By R. G. Hoskins. W. W. Norton and Company, New York. $4.00. 8½ x 5⅝; 388; 1941.

The importance of the delicate balance of the endocrine system in relation to man's physical and mental well-being is reason enough for the present intense interest, and rapid advance, in the field of endocrinology. The extensive and diversified clinical and laboratory experiences of Hoskins, in relation to the glands and their functions, have well qualified him for the task of preparing this comprehensive volume. In it he has attempted to bring together in a simple and understandable form, all the pertinent knowledge concerning the endocrines in health and disease. He has wisely departed from the general text-book mode of discussing the hormones from the standpoint of animal experimentation, and has developed the subject around human case histories. Throughout his discussions, the author points out that there still exist wide gaps in our knowledge of endocrinology, and indicates the lines along which further investigation is most urgently needed, and is likely to produce the most valuable results

The text is well supplied with illustrative material, and documentary records. The closing list of endocrine literature and the detailed index add to the volume's value for biologists, psychologists, and pre-medical students.

MUST WE GROW OLD?

By Barclay Newman. G. P. Putnam's Sons, New York. $2.50. 8 x 5¼; 269; 1941.

Another book for the layman giving a cheerful panoramic view of what research in the biological fields is doing toward the preservation and extension of human life. In Chapter I, The science of death comes to life, we read that "To man it has been given that he is master of his doom." In the next chapter, Our newest medical speciality—geriatrics [pathology of old age], the author discusses the increase in the average duration of life and the condition of the various organs in the aged. Geriatrists can be said "to be supplying the final proof that old age is pathological. . . ." In Chapter III, Death—always an accident?, we find that "Life spans are decided by chance, i.e., by (chemical) factors largely, but not entirely unknown." Then follows the longest section of the book (93 pages) on the effect that food factors have on the length of life. In this we gather that ultimately, by appropriate modification of food intake, the life of the individual can be extended indefinitely. The remaining chapters dealing with hormones, cancer, hypertension, tissue culture, enzymes, genes, etc., all present the same happy picture for the future of the human race. On almost every page the writer mentions the research work of well-known biologists, but he gives no reference lists nor does he furnish an index.

HEALTH OF WHITE SETTLERS IN SURINAM. *Colonial Institute at Amsterdam Special Publication No. LIIII. Department of Tropical Hygiene No. 16.*

By N. H. Swellengrebel, in collaboration with E. van der Kuyp. Colonial Institute at Amsterdam. Fl. 2, 10. 8⅜ x 6¼; viii + 118; 1940 (paper).

This report is not intended so much to encourage white colonization of Dutch Guiana as it is to evaluate the public health of the white settlers of the past and present. Although tropical disease is credited with some measure of the failures of the white colonies of the past, the present author believes that the big problem for future settlers will be economic rather than medical. With a reasonable amount of sanitary precaution, the coastal region and various parts of the inland regions of Surinam appear to be conducive to European settlement, that is, provided the Europeans, in their struggle for a livelihood, do not have to compete with Asiatic labor and Asiatic standards of living. The strongest recommendation listed, with regard to health, is that future white settlers be rigidly segregated from the native colored population in respect to living quarters, schools, and daily activities. The study is indicative of the enormous amount of research and field work that has been done in surveying the public health conditions of Surinam. It is well documented and indexed.

DAS MENSCHLICHE KNOCHENMARK: *Seine Anatomie, Physiologie und Pathologie nach Ergebnissen der intravitalen Sternalpunktion.*

By Karl Rohr. Georg Thieme Verlag, Leipzig. RM. 29.25 (cloth); RM. 27.75 (paper) (outside of Germany). 9¾ x 6½; 286; 1940.

Over 1800 sternal punctures, made over the course of seven years, are the main basis of this study of bone marrow as a blood-forming organ. The author divides the book into two parts. The first, or general, section gives a review of studies and theories concerning the embryological, anatomical, cytological, physiological and pathological aspects of the subject, and the development of the sternal puncture method for use in the study of bone marrow in the living subject. The second, or specialized, part presents the results of the author's investigations on erythropoiesis, leukopoiesis and thrombopoiesis under normal conditions and in the presence of leukemia, aplastic anemia, tumors of the bone marrow and infectious diseases. The 125 illustrations (some of them in color), which deserve special mention, add greatly to this valuable contribution to the literature of bone marrow and its functions.

BIOLOGICAL SYMPOSIA, *Volume III. Muscle. Series Edited by Jacques Cattell. Volume III Edited by Wallace O. Fenn. Jacques Cattell Press, Lancaster, Pennsylvania.* $3.50. 9⅜ x 6¾; 370; 1941.

This volume, containing 15 articles by various authors on muscle physiology, grew out of the symposium on muscle which took place at the American Physiological Society meetings at New Orleans in April, 1940. With the four papers originally presented—Muscle function as studied in single muscle fibers, by Robert W. Ramsey and Sibyl F. Street; Action potentials and conduction of excitation in muscle, by Emil Bozler; The regulation of energy exchange in contracting muscle, by Dugald E. S. Brown; and Changes during muscle contraction as related to the crystalline pattern, by Ernst Fischer—several other articles on closely related aspects have been grouped. The scope of interest of the volume has been expanded and rounded out by the inclusion of several contributions on muscle chemistry and myoneural transmission, grouped together at the end. Fenn has provided an introduction in which the history of muscle investigations and indications for future work are presented.

YOUR TEETH: *Their Past, Present, and Probable Future.*

By Peter J. Brekhus. With a Foreword by Irvine McQuarrie. University of Minnesota Press, Minneapolis. $2.50. 8 x 5; xvii + 255; 1941.

According to the writer of this treatise nearly all of our dental ailments, caries, pyorrhea, malocclusions, and to a certain extent anomalies, have one underlying cause—civilization. This theme is presented 255 + xvii times. Although the repetition becomes tiresome the belief is not without some justification, as Brekhus shows by evidence from racial and nutritional studies. He further discusses the history of dentistry, delves into the comparative anatomy and evolution of dental structure, describes the relation of oral to general health, and seeks for the evasive causes of caries and pyorrhea. The conclusion is drawn that at present our only hope is to inaugurate an inexpensive and all-inclusive plan of regular dental treatment for America's children. Hope for the future must center in increased dental research founded on the biological and physical sciences. *Your Teeth* is interestingly and amusingly written, and at the same time is based on numerous authoritative references.

ANNUAL REVIEW OF PHYSIOLOGY. *Volume III.*

Edited by James M. Luck and Victor E. Hall. Annual Reviews, Inc., Stanford University, P. O., Calif. $5.00. 8¾ x 5¾; viii + 784; 1941.

This indispensable *Annual* has temporarily lost its international character. This, however, is inevitable, since, in the first place, many European physiologists, for a number of reasons, have been unable to collaborate, and in the second, foreign periodicals have circulated most irregularly. In this county some of the contributors have entered war service and have been unable to prepare assigned articles. Nevertheless, we find this volume, with its 26 sections, a valuable addition to our reference books. Among the topics discussed we note: Energy metabolism, Respiration, Muscle, Blood, Peripheral circulation, and Endocrine aspects of the physiology of reproduction. Sweden is represented by a group of three articles on the special senses (hearing, visual receptors, and vibratory sensations and pain); England, by a section on histamine and anaphylaxis. As usual the volume has an author index and a detailed subject index.

SCIENCE AND SEIZURES. *New Light on Epilepsy and Migraine.*

By William G. Lennox. Harper and Brothers, New York and London. $2.00. 8 x 5¼; xiii + 258; 1941.

In the introductory chapter Lennox states the reasons for his book: first, as an aid to physicians who require in concise form the most recent information on epileptic and

migraine attacks; second, to help the patient to maintain a rational attitude toward his ailment and to cooperate with the physician; and third, to dispel the ignorance and prejudice of the general public. In large measure the book has achieved its purpose, although it leaves one with the knowledge that the surface has hardly been scratched in our attack on epilepsy. The latest scientific studies of cause, diagnosis, prevention, and treatment are recorded in these pages. This includes X-ray, electroencephalography, psychoanalytic treatment, and the use of drugs. In addition such sociological factors as education, occupation, and marriage are given due consideration. Lennox closes with a call for increased research in several fields which offer promise of success in the understanding and treatment of seizures.

AMERICA ORGANIZES MEDICINE.

By Michael M. Davis. Harper and Brothers, New York and London. $3.00. 8⅜ x 5½; viii + 335; 1941.

With increasing specialization of medical science there has occurred a marked change in patient-doctor relationships and a rising cost of medical services. Altered socio-economic conditions have made for increased disparity of treatment among various classes. Davis discusses these trends and the measures which have been used in coping with the problem, including public health centers, welfare services, clinics, health legislation and medical insurance plans, to mention a few. The efficacy of each of these actions and agencies is frankly criticized, pro and con. No definite program is put forward as a solution to the problem, but the author hopes that his book may diminish partisanship among the various agencies and further a form of organization which will promise adequate treatment for all people, at the same time maintaining individuality and freedom of choice for doctors and patients alike. This volume is thoroughly indexed and contains a bibliography of nineteen pages.

THE WORK OF THE KIDNEYS. *A Guide for Use with the Instructional Sound Film "The Work of the Kidneys."*

By Melvin Brodshaug and Helen Haggerty, in Collaboration with A. J. Carlson, H. G. Swann and F. J. Mullin. University of Chicago Press, Chicago. 15 cents. 7⅞ x 5¼; iv + 26; 1941 (paper).

CONTROL OF BODY TEMPERATURE. *A Guide for Use with the Instructional Sound Film "Control of Body Temperature."*

By Melvin Brodshaug and Helen Haggerty, in Collaboration with A. J. Carlson, F. J. Mullin and H G. Swann. University of Chicago Press, Chicago. 15 cents. 7⅞ x 5¼; iv + 25; 1941 (paper).

Both of these guides have been prepared as aids in making the most effective use of the sound films on these subjects which were prepared, in collaboration with the authors, from materials in introductory general courses in the biological sciences. High-school teachers and college instructors will find both the films and the guides useful as additional material in classroom work.

PEDIATRIC BIBLIOGRAPHY. *Monographs of the Society for Research in Child Development, Volume VI, No. 1 (Serial No. 27).*

By A. Graeme Mitchell. Society for Research in Child Development, National Research Council, Washington, D C. 75 cents. 9 x 5¾; vii + 119; 1941 (paper).

This 120-page bibliography was originally designed to be included in the third edition of *A Textbook of Pediatrics* (J. P. Crozen Griffith and A. Graeme Mitchell). Since it was found impractical to publish it there, it has been published separately. The list includes both textbooks and original articles from leading scientific journals, and is organized around the chapter headings of the above-mentioned volume, namely: the diseases of the various organs and organ systems, and diseases attributed to pathogenic organisms.

The work will be of value not only to students using the Griffith-Mitchell textbook, but to the general practitioner and the specialist in pediatrics.

THE BACTERIOLOGY OF PUBLIC HEALTH. *By George M. Cameron. C. V. Mosby Co., St. Louis.* $3.50. 8½ x 5½; 451; 1940.

Instead of accepting the dictum that a little knowledge is dangerous the author takes the position that some knowledge, however limited, can at times be helpful. He believes that in the case of parasitic diseases particularly, an understanding of the life and activity of the microorganism will be valuable to the layman. He, therefore, reviews briefly all the diseases caused by protozoa, bacteria, fungi, or viruses, and for each outlines the life cycle of the parasite, the mode of infection, the diagnostic tests, and specific therapy, if any. Well-selected references are given so that the interested persons can pursue the inquiry further. As a college textbook for supplementary reading in hygiene this volume will be found very useful.

PUBLIC HEALTH AND HYGIENE. *A Students' Manual. Third Edition. By Charles F. Bolduan and Nils W. Bolduan. W. B. Saunders Company, Philadelphia and London.* $3.00. 7⅞ x 5¼; x + 366; 1941.

Students of medicine, nursing, and public health will find this book valuable because of the large amount of substantial material it contains. The subjects presented are not only fairly complete but are also up to date. Thus the volume will also serve as a good review book for examinations. The wealth of material present can best be shown by a brief listing of some of the chapters. These are as follows: Life history of certain important insects, Principles of nutrition, Disinfection, Food poisoning, Dysentery and cholera, Our changing health problems, Diseases of later life, Food inspection, Public health nursing, Epidemiology and public health, Vital statistics. The material is well indexed but there is no bibliography.

NOTES ON DIFFUSE SCLEROSIS, DIFFUSE GLIOMATOSIS AND DIFFUSE GLIOBLASTOMATOSIS OF THE BRAIN WITH A REPORT OF TWO CASES. *Acta Jutlandica Aarsskrift for Aarhus Universitet XII, 3. By Lárus Einarson and Axel V. Neel. Einar Munksgaard, Copenhagen. Dan. Cr.* 2.50. 9½ x 6⅝; 56; 1940 (paper).

The authors discuss their classification of demyelinizing and sclerotic processes in the brain which they have presented in a previous work (1938) and report two further cases which they believe are pertinent to the question of the existence of a glioblastomatous transition form of diffuse sclerosis in the anatomical sense of the word. The clinical histories, autopsy findings and histological examinations of the brains of both cases are reported in detail. The pathogenesis of these diffuse blastomatous reactive growths and of diffuse glioblastomas is discussed and the possibility of transition forms considered. A list of references is included.

PERSON UND CHARAKTER. *By Rudolf Thiele. Georg Thieme Verlag, Leipzig.* RM. 1.50. 8⅛ x 5⅜; 43; 1940 (paper).

This is a brief discussion of the factors, mental and physical, environmental and inherited, that must be considered in the total make-up of a "personality." Characteristics thought important in aiding the typing of individuals according to constitutional or personality groups are indicated. The volume is annotated.

THE UNIVERSITY AND PUBLIC HEALTH STATESMANSHIP. *University of Pennsylvania Bicentennial Conference M-17. By Arthur P. Hitchens, Harry S. Mustard, Waller S. Leathers, and Charles-Edward A. Winslow. University of Pennsylvania Press, Philadelphia.* 50 cents. 9 x 6; 33; 1941 (paper).

PROBLEMS OF INTESTINAL OBSTRUCTION. *University of Pennsylvania Bicentennial Conference M-13. By John P. Peters, Owen H. Wangensteen, W. Osler Abbott, Allen O. Whipple and*

John A. Nelson. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 56; 1941 (paper).

THE RELATION OF DISEASES IN LOWER ANIMALS TO HUMAN WELFARE. *University of Pennsylvania Bicentennial Conference, M-14.*

By John R. Mohler, Raymond A. Kelser, and Cassius Way. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 39; 1941 (paper).

MODERN ASPECTS OF THE ANTITUBERCULOSIS PROGRAM. *University of Pennsylvania Bicentennial Conference, M-15.*

By J. Burns Amberson, Kendall Emerson, Wm. Charles White, and Louis I. Dublin. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 38; 1941 (paper).

CAUSE AND GROWTH OF CANCER. *University of Pennsylvania Bicentennial Conference. M-9.*

By Louis F. Fieser, Stanley P. Reimann, Peyton Rous, Warren H. Lewis, Margaret R. Lewis, and Balduin Lucké. University of Pennsylvania Press, Philadelphia. 75 cents. 9 x 6; 64; 1941 (paper).

DENTAL CARIES. *University of Pennsylvania Bicentennial Conference, M-11.*

By Henry Klein, Carroll E. Palmer, Basil G. Bibby, and Elmer V. McCollum. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 53; 1941 (paper).

MEDICAL PROBLEMS OF OLD AGE. *University of Pennsylvania Bicentennial Conference, M-4.*

By Louis I. Dublin, Howard T. Karsner, O. H. Perry Pepper, and Barney Brooks. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 46; 1941 (paper).

NUTRITION. *University of Pennsylvania Bicentennial Conference, M-5.*

By Conrad A. Elvehjem, Cyril N. H. Long, and Elmer V. McCollum. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 46; 1941 (paper).

HYPERTENSION. *University of Pennsylvania Bicentennial Conference, M-8.*

By Harry Goldblatt, Eugene M. Landis, and Alfred W. Adson. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 46; 1941 (paper).

BIOCHEMISTRY

ADVANCES IN ENZYMOLOGY *and Related Subjects. Volume I.*

Edited by F. F. Nord and C. H. Werkman. Interscience Publishers, Inc., New York. $5.50. 9 x 5¾; x + 433; 1941.

This fine volume inaugurates a plan "to provide a medium of publication in which significant discoveries or advances, either experimental or theoretical, are presented in a more comprehensive and unified fashion than is possible in regular journals, by authors who have been closely identified with this development."

The following subjects are discussed: Protein structure, by Henry B. Bull; Physical-chemical aspects of the problem of virus activity, by Luise Holzapfel; The specificity of proteinases, by Max Bergmann and Joseph S. Fruton; Metabolic generation and utilization of phosphate bond energy, by Fritz Lipmann; The chemical nature of catalase, by James B. Sumner; Enzymes and trace substances, by D. E. Green; Photosynthesis, facts and interpretations, by J. Franck and H. Gaffron; The bacterial photosyntheses and their importance for the general problem of photosynthesis, by C. B. Van Niel; Enzymatic processes in the living plant, by A. L. Kurssanov; Digestion in the lower vertebrates, by H. J. Vonk.

Graphs and figures appear in the texts, and each chapter concludes with a lengthy bibliography. Author and subject indexes are provided.

THE AVITAMINOSES. *The Chemical, Clinical and Pathological Aspects of the Vitamin Deficiency Diseases. Second Edition.*

By Walter H. Eddy and Gilbert Dalldorf. Williams & Wilkins Company, Baltimore. $4.50. 9 x 5¾; xiii + 519; 1941.

The first edition of this treatise appeared three years ago. Many changes in the present edition have been made in order to incorporate the newer knowledge in the field of avitaminoses. The volume has been enlarged by the addition of over 150 pages and a new chapter (III) has been added to furnish a clear picture of the relation of vitamins to cellular oxidation.

This discussion of vitamins from the clinical, chemical, and pathological points of view furnishes the student and the practitioner with a valuable reference work. Each chapter concludes with a list of references and there are 41 plates, 43 tables, and 28 figures in the text. In Appendix I is a discussion of the methods of studying avitaminoses, and Appendix II gives vitamin values of foods. Author and subject indexes conclude the volume.

DIE METHODEN DER FERMENTFORSCHUNG. *Lieferungen 6 and 7.*

Edited by Eugen Bamann and Karl Myrbäck. Georg Thieme Verlag, Leipzig. Lief. 6: RM. 25.20 (outside of Germany); Lief. 7: RM. 31.20 (outside of Germany). 11 x 8; Lief. 6: 1837–2172, Lief. 7: 2172–2588; 1941 (paper).

Among the many contributors to these two volumes are Kobel, Hackenthal, Nilsson, Bamann, Bovland, Holmberg, Schlenk, Stephenson, Woods, Northrup, Kunitz, Anson, Theorell, Lynen, Franke, Trolle and Harvey. Volume 6 gives detailed explanations of the preparation, purification, and properties of the many carbohydrases, nucleases, amidases, and proteases. Thrombase and the synthesizing enzyme oxynitrilese are also described. In Volume 7 are discussions (general and specific) of fermentation, glycolysis, anaerobic bacteria, dehydrases, cytochrome, and the isolatable oxyhydrases. A general review of the respiratory process is also given.

CHEMISTRY OF FOOD AND NUTRITION. *Sixth Edition.*

By Henry C. Sherman. The Macmillan Company, New York. $3.25. 8⅝ x 5⅜; x + 611; 1941.

By this latest revision, the sixth, the author has again brought up to date his well-known work. The four years which have elapsed since the appearance of the preceding edition (Q.R.B., Vol. 12, p. 383) have seen many new developments in the field of nutrition and the author has succeeded well in outlining and evaluating the recent discoveries. Almost every chapter has been revised and the latter half of the book has been rewritten to summarize the findings lately uncovered about vitamins, the B complex especially, and the so-called deficiency diseases. Included also is a new table on the copper and manganese contents of foods. The book is well documented and indexed and in all respects maintains a high standard as a college textbook.

LABORATORY DIRECTIONS FOR GENERAL ENDOCRINOLOGY.

By C. Donnell Turner. Student Book Exchange, Evanston, Illinois. $1.50. 9 x 5¾; v + 75; 1941 (paper).

Whether or not the author's arguments for the necessity of a course in general endocrinology for undergraduate students in zoology are generally held we cannot say, but it is upon this premise, and for this purpose that this manual has been prepared. The list of laboratory exercises has been designed to typify the procedures and techniques employed by present day research workers in the field of mammalian endocrinology. The rabbit, rat, and guinea pig are the primary subjects for experimentation, the work being divided into 44 exercises. This is to be supplemented by the study of histological sections of human material whenever available.

BIBLIOGRAPHY OF REFERENCES TO THE LITERATURE ON THE MINOR ELEMENTS AND THEIR RELATION TO PLANT AND ANIMAL NUTRITION. *Second Supplement to the Third Edition.*

Originally compiled by L. G. Willis. Chilean Nitrate Educational Bureau, New York. Free. 11 x 8½; 67; 1941 (paper).

This supplement (cf. Q.R.B., Vol. 15, p. 501 for mention of first supplement to third edition of this work) includes material that has accumulated since the first supplement was issued in 1940. The abstracts and references are obtained largely

from *Chemical Abstracts* and the *U. S. Experiment Station Record*, the source always being listed with each abstract. The index has been prepared with great care and will be found extremely useful to those working in this field. Following the plan originated in the first supplement a separate botanical index is included.

PROBLEMS AND TRENDS IN VIRUS RESEARCH. *University of Pennsylvania Bicentennial Conference*, M-2.

By Thomas M. Rivers, Wendell M. Stanley, Wilbur A. Sawyer, Thomas Francis, Jr., Richard E. Shope, Joseph Stokes, Jr., and Geoffrey Rake. University of Pennsylvania Press, Philadelphia. 75 cents. 9 x 6; 75; 1941 (paper).

CHEMOTHERAPY. *University of Pennsylvania Bicentennial Conference*, M-16.

By E. K. Marshall, Jr., John S. Lockwood, and René J. Dubos. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 42; 1941 (paper).

SEX

SEX VARIANTS. *A Study of Homosexual Patterns. In Two Volumes.*

By George W. Henry. With Sections Contributed by Specialists in Particular Fields. Sponsored by Committee for the Study of Sex Variants, Inc., Paul B. Hoeber (Medical Book Department of Harper and Brothers), New York and London. $12.50 for the two volumes. 9⅛ x 6; Vol. I: xxii + 546; Vol. II: viii + 633; 1941.

In the "Impressions" at the close of Volume II it is indicated that law and society have failed to solve the problems connected with homosexuality. In these two volumes a start toward a scientific approach to a solution has been attempted. Complete case studies of 80 homosexual persons are presented. Volume I contains the histories of 40 males and Volume II of 40 females; in each case the individuals are grouped according to whether they were bisexual, homosexual, or narcissist. For each individual a genetic chart, records of general impressions, the family background, personal history, physical examination (including a special study of the sex characteristics) and roentgenological study, and a summary are included. At the end of the second volume there are a number of collected studies, a brief chapter on "impressions" gained from the cases presented, and several appendices. The latter include discussions of masculinity-femininity tests, physical characteristics suggesting masculinity or femininity (with photographs), and anthropological data; a chapter on internal pelvic measurements of sex variants, by G. W. Henry, R. P. Ball, and J. R. Carty; a chapter on the gynecology of homosexuality, by Robert L. Dickinson; and a glossary of "the language of homosexuality" and a slang vocabulary.

In the "Impressions" the author expresses his view that the sex variant seems to be a by-product of civilization.

> In our present civilization he is an expression of his inability to meet the responsibility of establishing and maintaining a home which involves the rearing of children. The manifold demands made upon parents as a result of our high standards of living often discourage heterosexual adjustment and foster substitute sexual activity.

Query: Are there no homosexuals among primitive peoples?

Another interesting observation is:

> All persons who manifest violent emotional reactions to the sex variant warrant serious consideration. Such persons may be reacting to personal experience or they may be on the defensive lest they disclose their own unconventional desires and impulses.

These volumes are obviously and primarily for members of the medical profession and social welfare workers. The preparation of a third volume to discuss the results of these investigations is anticipated.

SPERMATOZOA AND STERILITY. *A Clinical Manual.*

By Abner I. Weisman. With a Foreword by Robert L. Dickinson. Paul B. Hoeber (Medical Book Department of Harper and Brothers), New York and London. $5.50. 9⅛ x 5¾; xvi + 314; 1941.

Leeuwenhoek first saw human spermatozoa almost 300 years ago, their function in reproduction has been definitely established for a long time, and yet it is only in recent years that any interest in the sperm cells and their contribution to sterility has been aroused. The meagerness of the available information becomes evident when one examines this book in which the author brings together and critically reviews the facts and ideas so far acquired about the subject.

The primary purpose is to give to the general clinician as well as to the specialist in urology and gynecology a broad view of the anatomy, physiology and biochemistry of sperm cells with reference to the processes of fertilization. Most of the book is devoted to the description of techniques for the collection and analysis of semen and the methods of diagnosing sterility in the male. Therapy in cases of sterility is also discussed and, in addition, there are chapters on the spermicidal action of certain drugs, on the study of semen in legal medicine, and on pregnancy tests. This work represents a pioneer enterprise and therefore is expected to be faulty in some respects. Nevertheless it serves to stabilize the scattered ideas on the subject and to lay the foundation for more adequate investigations. An excellent list of references is included.

FEMALE SEX HORMONES. *University of Pennsylvania Bicentennial Conference, M-6-7. By Edward A. Doisy, Philip E. Smith, Robert T. Frank, and Elmer L. Sevringhaus. University of Pennsylvania Press, Philadelphia.* 50 cents. 9 x 6; 58; 1941 (paper).

BIOMETRY

THE BULLETIN OF MATHEMATICAL BIOPHYSICS. *Volume 3, Number 4, December, 1941. Edited by N. Rashevsky. University of Chicago Press, Chicago.*

This number contains the following papers: A Neural Mechanism for Discrimination: IV. Monocular Depth Perception, by Henry Stanton; Some Preliminary Considerations Concerning Concentration of Oxygen in Tissue, by Ingram Bloch; Note on a Possible Application of Some Concepts of Topology to Asymmetric Organization of Protoplasm, by G. F. Gause; Statistical Distribution of Impedance Elements in Biological Systems, by A. M. Weinberg and A. S. Householder; A Theory of Steady-State Activity in Nerve-Fiber Networks: III. The Simple Circuit in Complete Activity, by Alston S. Householder; Distribution of Response Times, by H. D. Landahl; Application of the General Fluid Circuit Theory to the Chloride-Bromide-Deuterium Oxide Experiment, by H. C. Peters; The General Membrane Equilibrium Equation: Its Simple Derivation and Some of Its Biological Implications, by M. F. Morales and N. W. Shock.

STATISTICAL CALCULATION FOR BEGINNERS. *By E. G. Chambers. The University Press, Cambridge; The Macmillan Co., New York.* $2.00. 8½ x 5¼; vii + 110; 1940.

The purpose of this book, "to explain as simply as possible how to perform the calculations involved in the commoner statistical methods," is amply fulfilled by the writer. No attempt is made to give the mathematical basis of the techniques used. The subjects covered in the 92 pages are: averages, scatter, normal distribution, significance of mean and mean difference, correlation, regression and correlation ratio, chi square, contingency, and goodness of fit. The problems after each section (the answers being found at the end of the book) add to its teaching value. Four appendices of tables and one of numerical material for exercises are present. The volume is indexed.

PSYCHOLOGY AND BEHAVIOR

THE MASK OF SANITY. *An Attempt to Reinterpret the So-called Psychopathic Personality.*

By Hervey Cleckley. C. V. Mosby Co., St. Louis. $3.00. 8½ x 5½; 298; 1941.

In this book the problem presented by the type of individual on whom the psychiatrist makes the diagnosis "psychopathic personality" is considered. From the legal point of view these individuals are classed as sane, competent, and responsible for their own conduct. Examination of their life-stories reveals the fact that, even in the face of good intelligence, excellent opportunities, well-wishing friends and relatives who outdo themselves to help them to their feet, and the absence of any recognized psychosis or psychoneurosis, these individuals repeatedly fail to manage themselves and their responsibilities in a competent and satisfactory way. Since they are legally sane they are not eligible for admission to many state and federal hospitals, cannot be held for treatment when they are admitted, and are constantly being thrown back on the care of their families and communities.

Cleckley presents nine brief case abstracts of individuals who are so completely psychopathic in their behavior that they are unable to manage themselves, except for brief intervals, over many years, and whose records show repeated incarcerations and hospitalizations. In addition six cases are described of individuals who are able to keep up a front and carry their responsibilities in their communities, but who, in their private lives, show the typical irresponsible psychopathic behavior, usually associated with the use of alcohol. In Chapter 22 the typical and outstanding features of the patients under discussion are summarized. In the final chapters of the book Cleckley discusses possible psychodynamic factors. He suggests the term "semantic dementia" for this group of patients that, basically, seems devoid of all capacity to experience values and meaning in life, and recommends that they be considered, medically, as belonging to the psychotic group.

This book represents an incisive attempt to clarify a difficult problem with which so much confusion is associated, and should stimulate further thought and action on the part of psychiatrists generally. References to the literature are presented in footnotes and there is an index.

CONDITIONED REFLEXES AND PSYCHIATRY. *Lectures on Conditioned Reflexes, Volume II. By Ivan P. Pavlov. Translated and Edited by W. Horsley Gantt. International Publishers, New York.* $4.00. 9¼ x 6; 199; 1941.

When the history of the science of this epoch is written Pavlov will, without doubt, be ranked among the greatest of the biologists. His intellectual eminence was recognized long before his death and is even better appreciated in this book which contains selected addresses and unpublished papers prepared between 1928 and his death in 1936. Having carefully and thoroughly explored the mechanism of the reflexes, toward the end of his life Pavlov sought to apply the knowledge gained to the problems of human behavior and psycho-pathology. The papers which Gantt has assembled refer to this aspect of Pavlov's work. The articles are especially concerned with the relationship between the reflex mechanism and the functions of the nervous system and cortical centers. Pavlov's well-known experiments on the production of neurosis and his attempts to interpret, on the basis of these experiments, the manifestations of neurosis in man are summarized. There is no formal connection between the series of papers included in the volume, and so it is impossible in the space of a brief review to outline satisfactorily the contents. It can be said, however, that each of the articles reveals Pavlov's intentions to demonstrate the validity of investigating psychiatric and, in general, behavioristic problems by the experimental approach. Gantt, who has translated the articles and edited the volume, contributes an introduction in which he reviews Pavlov's work and clearly brings out its significance. This volume, together with the preceding one published in 1928, embodies all of Pavlov's public lectures from 1903 to 1936.

ANIMAL BEHAVIOUR. *Impulse. Intelligence. Instinct.*

By Johann A. Loeser. The Macmillan Co., New York and London. $2.00. 8½ x 5½; x + 178; 1940.

In this posthumous publication one finds an adequate summary of Loeser's ideas on animal behavior and of the kinds of facts on which his conclusions are based. The explanation of why animals act as they do has reflected the philosophy and also the theology of the period of the observer. Confronted, for example, by the seasonal migration of birds or their nest building, observers have introduced the concept of instinct, tropism, reflex, etc. In Loeser's views one almost sees the reverberations of the uncertainty principle. In agreement with some modern students of the subject he assumes that the reaction of an animal is to be regarded as the manifestation of a purposive act inasmuch as it is the resultant of a number of small voluntary acts. "These 'small actions', combined with a specific physical constitution which becomes effective in the animal's natural surroundings unite to produce *one* biologically purposive action." The author attempts to demonstrate the validity of this view by examining overt activities associated with self-preservation, reproduction, sociality, and migration. Some students of the subject accept this theory while others do not. As stated, it does not add much to a clarification of the question. When it is postulated that the overt activity of the animal is also a function of the physical constitution some will conclude that the concept of instinct thrown out of the door has reentered by the window.

FACTORIAL STUDIES OF INTELLIGENCE. *Psychometric Monographs, Number 2.*

By L. L. Thurstone and Thelma G. Thurstone. University of Chicago Press, Chicago. $1.50. 9¾ x 6½; v + 94; 1941 (paper).

No single index designed to measure mental ability can give a true picture of an individual's mental endowment. Such an index might stamp the individual as below average, whereas he may be far above average in some specific aptitude. Tests which will pick out such specific factors in mental ability are of special significance in numerous fields, important among which is vocational guidance. The authors of this monograph have for several years been engaged in such factorial studies of intelligence, and they have with considerable success isolated a number of primary abilities among college students. The present investigation was designed to determine whether these primary abilities could be identified in elementary school subjects, and whether some of the original conclusions could be sustained. The 60 tests which were devised are described briefly. Seven primary factors in mental ability were studied, and it was found that three of the tests could be selected for each ability, having a high saturation for one particular ability and a low saturation for the remaining six. Thus the writers have shown that, with a battery of 21 tests, several of the many factors in intelligence can be picked out with some degree of success on school children. This investigation indicates broad possibilities for the use of factor analysis in related fields.

COMPANIONSHIP PREFERENCE AND DOMINANCE IN THE SOCIAL INTERACTION OF YOUNG CHIMPANZEES. *Comparative Psychology Monographs, Volume 17, Number 1. Serial Number 85.*

By Vincent Nowlis. Williams & Wilkins Company, Baltimore. 10 x 6⅞; 57; 1941 (paper).

For this study in social behavior, five preadolescent chimpanzees (two males, two females, and one male castrate) were used. Data were collected with regard to companionship preferences, dominance status, food sharing, and general behavior. The method of paired companions was successfully used in the investigation, and second-by-second records of the behavior of the animals were made. Significance tests are applied to the statistical data whenever possible, and the results are presented in the light of such analysis.

Among conclusions worthy of note are the following: (1) each animal exhibited a consistent preference for one other animal, although this preference was seldom mutual; (2) the five animals were ranked in a consistent, progressive order of dominance by two separate tests of dominance

status, and no relationship was found between preference status and dominance; (3) food sharing was exhibited only by subordinate animals to their dominate partners, and no relationship was found to exist between preference status and food sharing; and (4) with regard to general social behavior, the larger portion of time was spent in grooming and play-fighting. A bibliography of 36 titles is appended.

FACTOR ANALYSIS TO 1940. *Psychometric Monograph No. 3.*

By Dael Wolfle. University of Chicago Press, Chicago. $1.25. 9¾ x 6¾; vii + 69; 1940 (paper).

It is universally accepted that ability in any field is determined by some combination of aptitudes or faculties. These several factors may be separated to some degree by specific tests. A statistical analysis may then be made of the efficacy with which these tests isolate the factors. This monograph is a review of the literature on factor analysis and discusses the following questions:

1. What is the reasoning common to the different factor methods?
2. How do the several methods differ from one another?
3. How may factors best be interpreted?
4. What have been the chief results of factor analysis?
5. What are the limitations and uses of factor analysis?

The author omits the detailed statistical procedures employed by workers in this field, and treats the subject as non-technically as possible. He clearly describes the advantages and disadvantages of each method of treatment.

So far factor analysis has had but limited practical application, this mainly in psychological research. The principal users of the method feel, however, that its future significance is as an exploratory instrument in the field of scientific research. It may point out certain underlying factors and relationships which may then be studied in the laboratory. The paper contains a complete index and a bibliography of 530 titles.

WOLF CHILD AND HUMAN CHILD. *Being the Narrative Interpretation of the Life History of Kamala, the Wolf Girl.*

By Arnold Gesell. Harper and Brothers, New York and London. $2.00. 10 x 6⅞; xvi + 107; 1941.

An account is presented, in narrative form, based on the diary kept by the missionary who found and cared for them in his orphanage in India, of the development until their death of two human children who were living in a den of wolves. One child, Amala, died the first year at the age of two, but the other, Kamala, who was eight when she was found, lived to the age of seventeen. It is her story, chiefly, that Gesell has reconstructed from the missionary's notes into a psychological biography. The gradual weaning of this child from the feral characteristics she showed when she first came to the orphanage to the ways of a human child make a fascinating and provocative story. Gesell follows out some of the broader connotations of this story in a chapter in which the interrelationship of heredity and culture are discussed. He states: "From the standpoint of genetic and clinical psychology the most significant phenomenon in the life career of Kamala is the slow but orderly and sequential recovery of obstructed mental growth." References to the other cases of feral and isolated children are made but there is no bibliography and source material is only occasionally quoted directly. The book is illustrated.

THE FACTORS OF THE MIND. *An Introduction to Factor-Analysis in Psychology.*

By Cyril Burt. The Macmillan Co., New York. $5.00. 8¼ x 5¼; xiv + 509; 1941.

Factor-analysis as a psychological methodology is presented in this book not merely as a statistical technique but as a mode of logical reasoning appropriate to the field of psychology. The material is organized in three parts: (I) The logical and metaphysical status of factors in psychology, (II) The relations between different methods of factor-analysis, and (III) The distribution of temperamental types. The

author states: "My primary object has been to determine a little more exactly the nature of so-called mental 'factors' by examining the form of proof by which those 'factors' are established." He carefully delimits the utility of factor-analysis, stressing its value for more precise and systematized description of the general structure of the mind or of the population, and minimizing its inferential and predictive use. There are two appendices: Appendix I. Working methods for computers, and Appendix II. Analysis of a matrix into its latent roots and latent vectors. The list of references includes 139 titles and there are author and subject indices.

A lucid and informative presentation of current viewpoints in this interesting field of psychological research.

INDIVIDUAL DIFFERENCES IN EMOTIONALITY, HYPOTHESIS FORMATION, VICARIOUS TRIAL AND ERROR, AND VISUAL DISCRIMINATION LEARNING IN RATS. *Comparative Psychology Monographs, Volume 17, Number 3, Serial Number 87.*

By Frederic M. Geier, Max Levin, and Edward C. Tolman. Williams & Wilkins Company, Baltimore. 50 cents. 10 x 6⅞; 20; 1941 (paper).

Using 57 male albino rats, these investigators were able to make 29 different measures of emotionality, vicarious trial and error, hypothesis formation, and discrimination learning. The data are presented in the light of tetrachoric correlations and "cluster-orthometric" analyses. A new form of graphic presentation, the factorgram, has been used to show graphically the extent of structural similarities of the variables. Among the significant conclusions of the report, the following appear most important: (1) timidity contributes neither negatively nor positively to learning or vicarious trial and error; (2) strong motivation (food) is a partial determiner of cognitive reaction; and (3) learning capacity in rats seems always to be relatively specific to the problem.

A short list of references concludes the monograph.

CRIMINAL YOUTH AND THE BORSTAL SYSTEM.

By William Healy and Benedict S. Alper. The Commonwealth Fund, New York; Oxford University Press, London. $1.50. 8¼ x 5¼; 251; 1941.

This book represents the results of a study made for the Criminal Justice-Youth Committee of the American Law Institute of the English Borstal System for training criminal youth. The purpose of the book is to consider possibilities for more effective methods of dealing with criminal youth in this country. The book is organized into three parts. In Part I, The Challenge, the present-day problem and ways it is being met in the United States are presented. In Part II, The Borstal System, the English handling of the same problem is described in detail. The origin and growth of the Borstal idea is presented, the general principles of Borstal training are outlined and the relationship of the boys to the staff, their homes and communities discussed. In Part III, Effective Training and Treatment, the Borstal system is critically evaluated and the desirability of incorporating its basic features into our own training institutions stressed. There is a bibliography and an index.

HUMAN NATURE IN THE LIGHT OF PSYCHOPATHOLOGY.

By Kurt Goldstein. Harvard University Press, Cambridge. $2.50. 7½ x 5; x + 258; 1940.

In this book, which comprises the William James Lectures delivered at Harvard University in 1938–1939, the author presents his conception of the nature of man which has evolved out of years of experience in the field of psychopathology and organic brain disease. He is concerned both with the proper methodology of research in studying human nature and with the ultimate views he has reached. His approach is essentially holistic. The basic generalization which he reaches is that abstract behavior represents the highest capacity of the human being. Of particular interest are his discussions of anxiety and fear, and of adaptation to the world. The chapters

on motivation and on the structure of the personality seem to contribute the least. The two final chapters, The individual and others and The fallacy of "Isolation" in social philosophy, are more philosophical in their orientation. Notes for each chapter are included and there is an index.

FORM DISCRIMINATION AS A LEARNING CUE IN INFANTS. *Comparative Psychology Monographs, Volume 17, Number 2, Serial Number 86.*

By Bing-Chung Ling. The Williams & Wilkins Co., Baltimore. $1.50. 10 x 6⅜; 66; 1941 (paper).

This monograph reports a study of geometric form discrimination in infants. Over fifty infants, ranging in age from six to twelve months, participated in the study which lasted fourteen months. Six series of experiments were used involving changes in the experimental blocks in respect of spatial arrangement, size, number, and order. The data obtained were analyzed in detail and the conclusions presented under two headings: A. Perceptual processes, and B. Learning processes. Of particular interest is the evidence pointing to a capacity for abstraction in the infants within the age levels studied. This study represents an interesting contribution to the problem of the thinking function in the first two years of life. There is a bibliography of 65 titles.

LIONS ON TRUST.

By Cleland Scott. The Macmillan Co., New York. $3.00. 8¼ x 5¼; 317; 1940.

A great deal of interesting, detailed information regarding the behavior of wild and of domestic lions. The author has hunted lions on and near his large farm in East Africa and has raised them to adulthood as "pets" in his home. He stresses the conclusion that lions can differ individually to a remarkable extent. The book contains also a good chapter on game preservation and many unusual remarks on the behavior of hunters.

THERAPEUTIC ADVANCES IN PSYCHIATRY. *University of Pennsylvania Bicentennial Conference, M-3.*

By Edward A. Strecker, Abraham A. Brill, Nolan D. C. Lewis, and Arthur H. Ruggles. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 34; 1941 (paper).

THE BEGINNINGS OF SOCIAL BEHAVIOR IN UNICELLULAR ORGANISMS. *University of Pennsylvania Bicentennial Conference N-C.*

By Herbert S. Jennings. University of Pennsylvania Press, Philadelphia. 25 cents. 9 x 6; 17; 1941 (paper).

DE OMNIBUS REBUS ET QUIBUSDEM ALIIS

A HISTORY OF MAGIC AND EXPERIMENTAL SCIENCE. *Volumes V and VI. The Sixteenth Century.*

By Lynn Thorndike. Columbia University Press, New York. $10.00 for the two volumes. 8⅝ x 5⅝; Vol. V: xxii + 695, Vol. VI: xviii + 766; 1941.

Volumes III and IV of this work dealing with the 14th and 15th centuries have already been reviewed in these columns (cf. Q. R. B., Vol. 10, p. 375). Further notice seems called for, however, owing to the fact that the sixteenth century, the subject of the last two volumes, marks a critical period in the development not only of scientific thought but of belief in magic as well.

The attitude of the modern devotee of magic is not so much unscientific as frankly anti-scientific. This is due somewhat to the tendency of modern science to become esoteric, owing to the placement of emphasis on the acquisition of knowledge to the neglect of its dissemination. There is a certain type of mind that seems actuated by a sort of professional jealousy, which realizes unwillingly its intellectual inability to keep abreast of advancing scientific thought, and which, therefore, resorts to a belief in magic as a means of compensation. A belief in the supernatural is a logical corollary.

In the medieval period belief in magic did not necessarily imply belief in the supernatural. The authenticity of magi-

cal phenomena was accepted, but these were interpreted as the result of natural factors as yet unknown. Today, belief in magic is incompatible with belief in science, but in the dark ages the magician and the scientist were generally blended in the same individual. Goethe's great dramatic poem celebrates a philosopher whose activity was devoted equally to the search for the elixir of life and the extermination of malaria.

The story is frequently told of how Kepler, the greatest astronomer of his time, had to choose between casting horoscopes for the European nobility or death by starvation, and there has been much speculation as to how distasteful such work must have been to one of his mentality. But the truth is that Kepler probably shared the faith of his most superstitious patrons in his occult prognostications. The difference between Kepler and the modern fortune-teller is that Kepler believed that the planets were in some mysterious but natural way connected with human welfare, and that by formulating his laws of planetary motion he might be able to throw light on this connection, whereas the astrologer believes the connection to be supernatural, and therefore not amenable to scientific investigation.

The alliance between science and magic was of course only a temporary one. That it lasted as long as it did was owing to the reliance of both on authoritarianism. As long as Aristotle, Hippocrates, Pliny, and Galen constituted the supreme court of last resort in the settlement of disagreements about scientific matters, the wheat and the tares could continue to grow together in amity, but when Galileo dropped his balls from the tower of Pisa it became inevitable that science and magic should arrive at the parting of the ways. The history of the sixteenth century is the story of the divarication between two incompatible types of human mind. Now what were some of the beliefs that the sixteenth century savants accepted? Thorndike enumerates many of them. They were chiefly of a biological nature—that salamanders can live in fire; that corpses will bleed in the presence of a murderer; that mice, flies, and worms can be spontaneously generated from putrefaction, and birds from driftwood; that geese come from barnacles, etc. There was also a considerable body of quack medicine that seems like an adumbration of "The Long Lost Friend" —which of course it was—such that peony and emerald, the lungs of a fox, and the dung of a white dog are specific medicine for epilepsy, asthma, and quinsy, respectively; that wearing a belt made of wolf's intestine will cure colic; and that hydrophobia can be contracted by sleeping beneath a tree whose bark has been chewed by a rabid dog. From the standpoint of folk-lore perhaps the most interesting item is that if a female snake, during copulation, bites off and swallows the head of the male, the first act of the progeny will be to avenge the death of their sire by killing the dam—a strange transferal of the Orestes myth to zoology. The thoroughness with which Thorndike has covered this field is testified to by the index to all six volumes which appears at the end of the last. It occupies 149 pages, and as about 40 authors per page appear among the entries, it serves as a bibliography of nearly 6000 items. It is difficult to imagine a scholar in any field at all who could not find something of interest to his work in this monumental book.

ANTITHETICAL VIEWS ON TWINNING FOUND IN THE BIBLE AND SHAKESPEARE. *Reprinted from Southern Medicine and Surgery, Volume 103, Number 3, 1941.*

By Groesbeck Walsh and Robert M. Pool. Obtainable from the Authors, Fairfield, Alabama. Free. 10⅜ x 7⅞; 10; 1941 (paper).

That Shakespeare was a student of the Scriptures and extensively influenced by them is a well-authenticated fact. In at least one respect, however, he did not show the traditional views of the Old Testament Hebrews. This is indicated by his treatment of the personalities of the three pairs of twins that figure in two of his comedies. There are no twins in his tragedies. On the other hand, the only two pairs of twins in the Scriptures are tragic figures.

The strong ties of family love that unite Sebastian and Viola contrast widely with the jealousy of Jacob toward Esau, a jealousy which survives today between the Zionists and the Arabs in Palestine. The story of Jacob and Esau is generally considered to be epic history of the beginning of the strife between Israel and Edom, but the present writer believes that the somewhat similar story of Phares and Zerah who did not become the progenitors of a family feud indicates that the question goes much deeper, and its answer involves a study of the folk-lore of both peoples, as well as of such matters as mancinism and freemartinry, and various references to twins, not only in the two authors concerned, but also in the works of Mahomet and H. H. Newman.

Despite the thoroughness of the authors in this piece of research, the reader is left with the feeling that there is still more to be said in this matter Why, for instance, is it considered disadvantageous for a javelin thrower to be lefthanded, and at the same time an advantage to the slinger? And what is the evidence that Simon Peter was left-handed? And why did Ehud, who was left-handed, carry his dagger on his right thigh? Let us hope that these matters have been elucidated in the additional manuscript which the authors have prepared and for which they are seeking a publisher.

THE DEVELOPMENT OF THE SCIENCES. *Second Series.*
Edited by L. L. Woodruff. Yale University Press, New Haven. $3.00. 9 x 5¾; 336; 1941.

This is a splendid piece of work that cannot be too enthusiastically recommended. Within the past few years a great many books have been reviewed in these columns, all of which have had the same end in view—to give a more or less detailed general survey of the universe as contemplated by modern science. But modern science is a very complex thing, especially as the result of new discoveries and theories based upon them in the last few years, and many of the older generation have difficulty in recasting their ideas so that they may read these modern works intelligently.

The work now under discussion approaches the problem from the historical standpoint. It puts the main emphasis not on what the teaching of modern science is, but how it came about. Its outlook is dynamic rather than static, and readers who wish to acquire a familiarity with present day science are urgently advised to begin by reading this symposium. Its eight chapters deal with mathematics, astronomy, physics, chemistry, geology, biology, psychology, and medicine. The important incidents in the careers of those who founded and developed these sciences are recounted. The wealth of biographic material brings these characters to life again in the reader's imagination. The book is well documented and provided with index and bibliography.

RUBBER AND ITS USE.
By Harry L. Fisher. Chemical Publishing Company, Brooklyn, N. Y. $2.25. 8½ x 5⅜; xvi + 128; 1941.

This is a book that grew out of the experiences of the author during his seventeen years as a research chemist in lecturing on the chemistry and technology of rubber. He discusses in order: the history of the rubber industry, sources and production of crude rubber, properties of crude and vulcanized rubber, the importance of vulcanization, compounding and vulcanizing rubber, manufacturing rubber, latex manufacturing processes, synthetic rubbers, and various rubber derivatives. This volume should prove most interesting and useful not only because of its authoritative and practical treatment but because its style is such that it can be read and easily understood by the general reader. The new developments in synthetic rubber which are here described should prove of especial interest and value to laymen in view of the constant and ever-increasing emphasis on this important phase of the rubber industry. The book is appropriately illustrated and there is a very helpful list of reference works for supplementary reading. A very complete index concludes this timely work.

DER GESTALTKREIS. *Theorie der Einheit von Wahrnehmen und Bewegen.*

By Viktor von Weizsäcker. Georg Thieme Verlag, Leipzig. RM 9.00 (cloth); RM. 7.50 (paper) (outside of Germany). 9⅛ x 6¼; viii + 179; 1940.

The author develops his philosophy on the "Gestalt Cycle" from a study of pathological conditions of the nervous system, and conditions for perception and for motion (anatomical, physiological, and in terms of space, time, and form). Perception and motion are explained as manifestations of a resting state. Like Paremenides, he understands by "existence" universal, immutable, invariable being, and the progressive changes we perceive in "life" (between birth and death) as a semblance of existence.

DIE BIBLIOTHEK EINES WITTENBERGER MEDIZINERS UM 1790 (*Chr. Fr. Nürnberger*). *Abhandlungen zur Geschichte der Medizin und der Naturwissenschaften, Heft 33.*

By Heinrich Kramm. Verlag Dr. Emil Ebering, Berlin. RM. 3.90. 9⅜ x 6¼; 96; 1940 (paper).

This list of 471 individual books and sets on scientific subjects, presented by Christian F. Nürnberger (1744–1795) to the library of Wittenberg University, Halle, is preceded by an introductory chapter on the history of the University Library, mention of collections presented by other persons, and a brief sketch of the life of the donor of this collection. It is of interest mainly to the medical historian.

STUDIES IN THE HISTORY OF SCIENCE. *University of Pennsylvania Bicentennial Conference.*

By E. A. Speiser, Otto E. Neugebauer, Hermann Ranke, Henry E. Sigerist, Richard H. Shryock, Evarts A. Graham, Edgar A. Singer, and Hermann Weyl. University of Pennsylvania Press, Philadelphia. $1.50. 9 x 5¾; 123; 1941.

This is a series of lectures on different phases of the history of science. They are not connected except that they were all given at the bicentenary of the University of Pennsylvania. They are well documented but there is no index or bibliography.

ADVENTURES IN GOOD EATING. *Good Eating Places along the Highways of America. Eighth Edition.*

By Duncan Hines. Adventures in Good Eating, Inc., Bowling Green, Kentucky. $1.50. 7½ x 5; 316; 1941 (paper).

LODGING FOR A NIGHT. *A Directory of Hotels Possessing Modern Comforts, Inviting Cottages and Modern Auto Courts, also Guest Houses Whose Accommodations Permit the Reception of Discriminating Guests. Fourth Edition.*

By Duncan Hines. Adventures in Good Eating, Inc., Bowling Green, Kentucky. $1.50. 7½ x 5; 318; 1941 (paper).

A CHALLENGE TO SCHOLARSHIP. *University of Pennsylvania Bicentennial Conference, M-D.*

By W. Mansfield Clark. University of Pennsylvania Press, Philadelphia. 50 cents. 9 x 6; 20; 1941 (paper).

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